



For Reference

NOT TO BE TAKEN FROM THIS ROOM

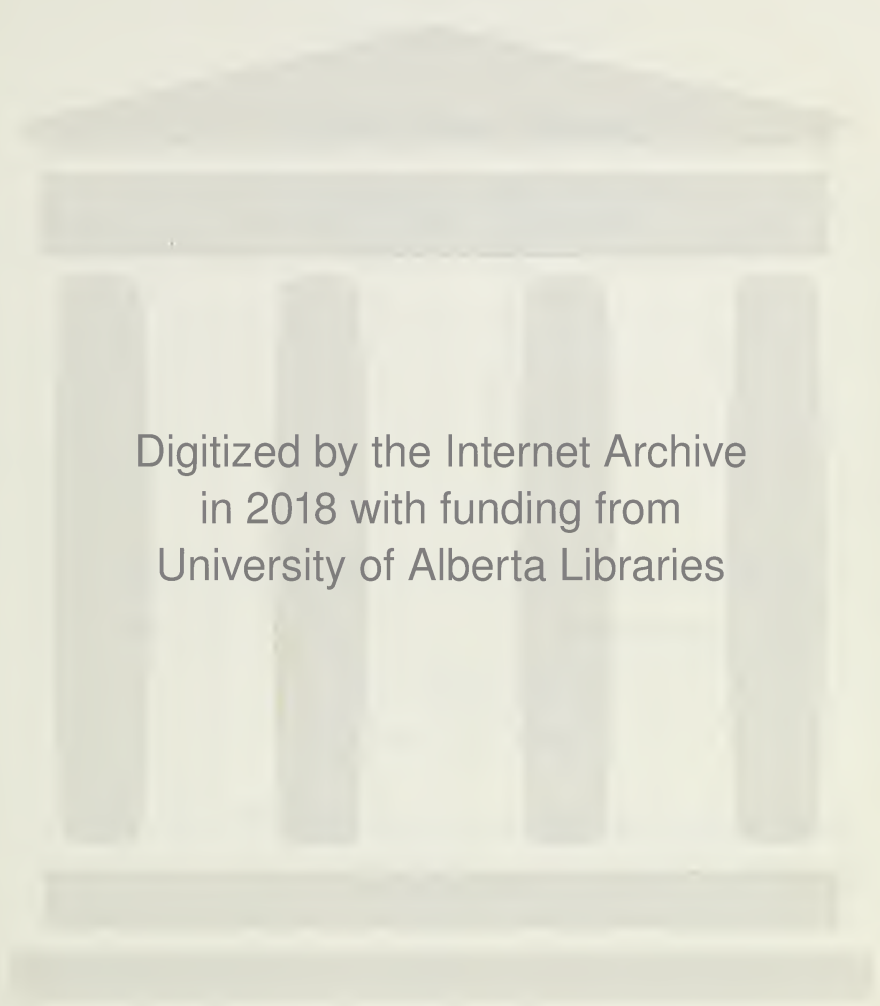
FACTORS RELATED TO THE KEEPING QUALITIES
OF CUT FLOWERS

Lorene Louise Kennedy
Department of Horticulture
Department of Botany

University of Alberta

Ex LIBRIS
UNIVERSITATIS
ALBERTAENSIS





Digitized by the Internet Archive
in 2018 with funding from
University of Alberta Libraries

<https://archive.org/details/factorsrelatedto00kenn>

FACTORS RELATED TO THE KEEPING QUALITIES
OF CUT FLOWERS

Lorene Louise Kennedy
Department of Horticulture
Department of Botany

A THESIS
submitted to the University of Alberta in
partial fulfilment of the requirements for
the degree of
MASTER OF SCIENCE

This thesis represents one-half the total work.

Edmonton, Alberta
April, 1943

TABLE OF CONTENTS

	Page
Introduction	1
Literature Review.	4
Experiments, Part I.	18
Discussion of Results.	34
Experiments, Part II	38
Methods.	38
Results.	46
Preliminary Experiments.	46
Main Experiment.	51
Discussion of Results.	57
General Discussion	59
Summary.	65
Acknowledgments.	66
References	67

FACTORS RELATED TO THE KEEPING QUALITIES OF CUT FLOWERS

Lorene Louise Kennedy

INTRODUCTION

The problem of extending the life of flowers after they have been cut from the plant is one which has interested people for many years. The work done in this field has been undertaken with the object of increasing the life of the flowers because of economic advantages. That is, practical treatments have been sought whereby the grower, florist and buyer can improve the keeping qualities of the flowers.

In the experiments undertaken by the various workers no attempt has been made (as indicated by the available literature) to carry out a program in which physiological processes of the flower such as transpiration and respiration have been measured and correlated with keeping qualities. Laurie (6) does suggest that a beneficial treatment, that is, one which would improve the keeping qualities of the flower, would increase transpiration rate and reduce respiration rate, but he does not give any experimental evidence to support this statement. These men recorded the number of days the flowers lasted in the various experiments and the treatments were recommended or rejected on this evidence. From a study of the literature

it is readily seen that there is great variation and inconsistency in the results obtained: a chemical is rejected in one report and highly recommended in another. A part of this confusion undoubtedly arises from the different conditions under which the experiments were run but the experimental work on this subject will never rest on a firm basis until some attempt is made to understand the normal physiology of the flower concerned and the effect of the various treatments on the metabolism of the flower. Furthermore, each species must be thoroughly understood physiologically before one can begin to improve its keeping qualities. The method of simply trying out different treatments on the flowers in the hope of finding a favorable one is at best a haphazard one and is an elementary stage in coping with this problem.

Beside the fact that better progress would be made in finding good practical methods of improving the keeping qualities of flowers by the physiological method this problem offers an interesting approach to the general question of longevity. Why is it that some plants lose their flowers in a few hours, others not for months? Of course it is known, with regard to flowers, that longevity is intimately related to fertilization and seed setting. Flowers that must be cross-fertilized last longer than those normally self-fertilized: where plants produce only a few or only one flower in a season, such as some of the orchids, the flowers last longer than those produced by plants which give rise to a profusion of flowers in a season. But what are the different mechanisms involved here? The writer is well aware

that it is easy to raise such questions and very difficult to answer them, nevertheless even the raising of such questions is of some use in the progress of understanding this problem.

In this regard Molisch (11) in his discussion of longevity of plants states, "In addition to the art of maintaining plants in a healthy condition during their normal span of life and up to their natural death we are interested also in extending their lives beyond the normal period, for this gives us a deeper insight into various phenomena of plant life, especially into the nature of old age and its associated decadence." He is concerned here with the longevity of the whole plant but the same holds true for a study of the longevity of the various organs.

After a survey of the various methods used in attempting to improve the keeping qualities of cut flowers it was considered that the chemical method was best suited to the pursuance of this work. The object of these experiments is to discover if certain physiological factors or processes are related to the keeping qualities of cut flowers and to determine what this relationship might be.

The work reported in this thesis may be divided into two parts. In Part I a search was made for a chemical or chemicals which induced a marked response from a given flower, so that, starting with this response, the physiological factors so affected might be studied and attempt made to understand what effect the chemical had on the flower. At the same time many recommended chemical treatments were given at least one trial.

Having chosen the chemicals and the species of flower to be used, the writer proceeded in Part II to study under controlled conditions the physiological reactions of the flowers as interpreted through transpiration and respiration responses and to correlate them with keeping qualities.

LITERATURE REVIEW

Although all the methods put forward by the various workers were not studied in this thesis it was thought that a general review of the literature would be of value in the understanding of this many-sided problem. The approaches which have been taken may be discussed under the following headings:

1. Mechanical Methods: these methods include various stem treatments, types of containers, hardening etc.
2. Physical Methods: such methods involve variations in the temperature, humidity and gaseous atmosphere around the flowers.
3. Chemical Methods: these methods are concerned with the addition of chemicals to the water in which the flowers are kept.

Mechanical Methods

It is in this category that many "popular" practices fall. These practices are not based on experimental data and do not merit serious consideration, however they illustrate one

approach to this problem.

(1) Cutting stems under water. The practice of cutting the flower stems under water before they are placed in water instead of ordinary cutting in air has been advocated. The reason given is that this prevents air bubbles in the conducting vessels of the xylem and facilitates the rise of water in the stem. Laurie (6) claims that the effect of cutting stems under water varies with the species of flower. Those flowers such as sweet peas and asters which have small conducting vessels were aided by this practice while flowers such as stocks with large conducting elements were not benefited.

(2) Type of container. Many recommend a deep container in which most of the flower stem is in contact with water which will prevent evaporation from the sides of the stem. Fourten and Ducomet (1) state that flowers keep better in shallow containers. Laurie (6) showed by experiments in depths of water ranging from one-half inch to ten inches that flowers keep as well and often better in shallow containers. The reason given is that less stem surface is exposed to bacterial action in shallow containers. He also demonstrated by sealing various parts of the stem that the greatest amount of water is absorbed through the cut end of the stem and thus deep water does not aid in absorption.

(3) Hardening flowers. The question of whether flowers should be "hardened" is more important than the foregoing ones as it is a commercial practice. "Hardening" is the practice of placing the flowers in a deep receptacle of cold water in a cool dark place for several hours before they are subjected to

either shipping or ordinary room conditions. Tincker (22) states that this practice is of agreed practical importance among flower growers in England and on the continent. It has been found through experience that preliminary saturation before shipment (anywhere from twelve to twenty-four hours) which induces the plant tissues to take up a maximum amount of water greatly prolongs the life of many species of flowers. This hardening is also practiced by florists for twenty-four to forty-eight hours before the flowers are offered for sale. However, there has been no experimental work carried out using this treatment. This is a good illustration of the many practices for prolonging the life of flowers which appear to have no experimental basis but are firmly established as cultural practices. It would be reasonable to suppose that the conditions of low temperature and high humidity would be beneficial to the flowers.

Physical Methods

These are methods involving variation in the temperature, humidity and gaseous atmosphere around the flowers. These methods have to do with storage procedure as it is only in storage that these factors can be controlled.

Hitchcock and Zimmerman (3) carried out experiments in which cut flowers of cosmos, coreopsis, dahlia, carnation, rose and gladiolus were subjected to varying humidities and temperature. With constant temperatures they found that coreopsis lasted four times as long at 5°C. as at room temperature (21°C. approximately). Neither cosmos nor dahlia ^{was} ~~were~~ benefited

by low temperatures. When coreopsis flowers were kept at room temperature during the day and at 10°C. during the night a gain of two days in keeping time resulted. A further gain of two days showed that high and low temperature alternation is more effective on a twenty-four hour basis than on a day and night basis. Coreopsis stored for three days at 5°C. lasted an additional three days when removed to room temperature while fresh flowers kept under room conditions lasted three days. This is evidence in favor of the positive side of the controversy about whether storage at low temperature adds to the life of the flower or merely holds the flower in good condition. On the other hand Ries (18) says that for each additional day carnations are stored at low temperature they will last one day less after removal to room temperature. That is, the life of a carnation is the same whether it is held in cold storage or kept at room temperature. Roses and carnations in the Hitchcock and Zimmerman experiments were also benefited by low temperatures to about the same extent.

In further work these men modified both humidity and temperature to determine the effect of humidity on the keeping qualities of the flowers and also to determine if this effect is modified by temperature. They showed that carnations kept two to three times as long in an atmosphere of 98% saturation as they did in an atmosphere below 80% saturation. Carnations lasted longer at high humidities if the temperature was low but humidity was a limiting factor even at 10°C.

Thornton (21) studied the influence of temperature,

moisture and carbon dioxide treatment on the duration of flowers. His principal material was roses which he sealed in cans containing a weighed amount of dry ice and held at temperatures of 3 to 14°C. After they were removed from storage the roses were held at room temperature with stems in water to compare the opening of the flowers and the time of petal fall with freshly picked roses. He found that after seven days treatment with a range of 5% to 15% carbon dioxide the rose buds lasted as long as the untreated ones held under the same conditions of temperature for three days. Treatment longer than seven days resulted in rapid loss of petals when the flowers were removed to room conditions. Thus roses may be kept an additional four days in carbon dioxide storage. The effectiveness of the carbon dioxide was modified by moisture conditions as roses did not open as much if held with their stems wrapped in moist paper as when the stems were in water. Definite varietal differences were found among the roses in regard to the concentration of carbon dioxide which would injure the petals and these differences would need further study if the method was to receive commercial application. These results illustrate the fact so often shown by experiments with flowers, that different species (for example see Hitchcock and Zimmerman) and even different varieties react differently to identical treatments due probably to inherent differences whose nature has not yet been resolved. Thornton states that while the carbon dioxide treatment held flowers in the bud stage in no case did it benefit opened flowers.

Longley (8) studied the effects of various gases under

storage conditions. The flowers, Briarcliff and Talisman roses and Matchless carnations, were kept with stems in water and stored in sealed cans at a temperature of 1°C. approximately. The roses treated with carbon dioxide (8% to 10%) lasted slightly better than the untreated stored lots under room conditions but not as well as freshly cut flowers. He also tried carbon dioxide treatment of roses stored with stems in 10% sucrose solution and found that although the roses were retarded in opening they suffered petal injury. With the carnations the flowers treated with carbon dioxide lasted best of the storage lots and the life under room conditions was prolonged one to two days. It was found best to store the carnations with their stems in water also, rather than in sucrose.

Whiteman and Wright (24) worked with Wedgewood iris blooms in the bud condition. They demonstrated that the flowers held in storage with stems in water remained tight at 0°C. but not at 4°C. or 10°C. However, none of the stored flowers lasted as long as fresh picked flowers under room conditions.

M. S. Neff has done a great deal of work on the storage of cut flowers. Preliminary experiments (12) indicated that French marigolds stored best at a temperature of 4°C. After several weeks storage the flowers lasted better if they had been stored with stems wrapped in wax paper rather than stood in water.

These observations were followed by experiments with carnations (13). The work deals with the results of storing carnations with stems in water as compared to storing them "dry

pack". The term "dry pack" refers to storage with the stems out of water. For dry pack storage Neff found that the best method was to place the flowers in sealed containers. When removed to ordinary conditions of temperature and humidity the keeping qualities of the stored flowers were observed and compared with those of freshly picked flowers. He showed that carnations stored dry pack for thirty-two days lasted longer at room temperature than those stored with stems in water and on the average lasted as long as freshly cut flowers. Thornton (21) also found storage with stems out of water beneficial. Neff found that fresh carnations placed in water under room conditions gain in weight immediately and reach a maximum in thirty-six hours. Carnations stored dry pack behave in a similar manner but those stored with stems in water lost weight steadily under room conditions. The decrease in weight is strongly correlated with poor keeping quality. He showed that carnations cut at midday were many times better than those picked in the evening. On this point he is supported by work done on gladioli by Pridham and Thompson (16) which demonstrated that flower spikes cut during the heat of the day keep better than those cut in the morning or evening. To account for this fact these men advance the theory that the cells are in a state of reduced turgidity and for this reason are better able to stand the shock of cutting and removal to abnormal conditions.

In a carbohydrate analysis of the flower heads of dry pack carnations as compared with those stored with stems in water and those freshly picked, Neff found that the flowers stored

dry pack were only slightly lower in total sugars, dextrin and starch than freshly cut flowers; on the other hand flowers stored in water were reduced in these substances by approximately one-half. This analysis suggests considerable utilization of available foods by flowers stored in water. The conclusion is that dry pack storage in conjunction with low temperature and high percentage humidity (the atmosphere inside the containers is saturated) gives excellent storage results with carnations. He propounds the theory that flowers stored with stems in water immediately take up water and thus moisture is available for physiological processes. Thus even at low temperatures the flowers will tend to complete their developmental cycle. Cell development can progress only when there is sufficient moisture to maintain high turgor pressure; reducing water content therefore reduces the rate at which the flowers mature. Dry pack flowers have just enough moisture around them from their transpiration to keep them from becoming desiccated but not enough to initiate any chemical reactions. He believes this factor more important than reduced respiration, due to the presence of carbon dioxide in the sealed containers and low temperatures.

Neff next turned his attention to storage of roses. In extensive experiments (14, 15) he was able to show that roses too kept better when stored dry pack. Furthermore the rose buds opened least that had been exposed to preliminary wilting of twelve to eighteen hours which reduced water content, -- a method of maintaining the buds in a tight condition. However, the petals tended to take on a bluish cast both in storage and with carbon

dioxide gas treatment. This loss of fresh color was accompanied by loss of odor. In later work he found that light was an important factor in storage as there was less tendency for the petals to become blue when the flowers were illuminated in storage.

Chemical Methods

These methods are concerned with the placing of one or more chemicals in the water in which the flowers are kept. They generally refer to keeping the flowers in chemical solution under room conditions but the definition has been extended here to include treatment of flowers by chemicals under storage conditions.

Fourten and Ducomet (1) ran experiments in which they tried a great number of chemicals in different concentrations classifying them as acids, e.g., hydrochloric, nitric; bases, e.g., sodium hydroxide, potassium hydroxide; salts, e.g., sodium chloride, potassium sulphate; organic substances, e.g., tartaric acid; aseptic substances, e.g., boric acid and potassium permanganate. Compounds were described as favorable, indifferent, aseptic and definitely injurious. Five to ten flowers were placed in each container and each treatment was replicated seven times. Some of the favorable compounds were: chloral (trichloroacetaldehyde), potassium nitrate, potassium hydroxide, potassium sulphate, potassium phosphate, sugars, ether, glycerine, calcium hydroxide, calcium chloride, ethyl alcohol and ammonium phosphate. Favorable treatments extended the life of primula, myosotis, asperula and silene from four to nine days. As these workers had no trouble with bacterial action the compounds designed to

render the water aseptic had no marked effect. The authors say that the chief problem is to get sufficient water to the flower head but no statement of underlying principles was made. Their work would have been more useful to other workers in this field had it included more extensive descriptions of the experimental setup, materials used and data obtained; however it represents the first attempt to use chemicals to improve the keeping qualities of cut flowers.

In further work reported by Tincker (22) these men recommend sugar as one of the most useful substances and superior to most of the other compounds listed above. They state that 7% to 10% sugar solution is the best treatment for roses.

Grinstead (2) claims that camphor added to the water will stimulate the absorption of water by the blooms and the presence of charcoal will keep down bacterial action. Flowers that have wilted will revive if placed in a solution of salt and warm water.

Knudson (5) following the chemical lead of Fourten and Ducomet was unable to substantiate their favorable results. In extensive experiments employing some ten thousand cut flowers and many different chemical solutions he found that in no case were striking results obtained in regard to improved keeping qualities. The only recommendation he is prepared to make is that a mixture of strontium and calcium chloride or zinc sulphate will prevent bacterial action in the water, if this takes place. He claims that bacterial action is an important factor because of two things: (1) bacteria clog the conducting vessels of the stem

and prevent the ascension of water; (2) the bacteria give off toxic substances as by-products of their metabolism which are harmful to the flower. However, Knudson thinks that it is better to cut the stem end daily to remedy this condition rather than to use chemical substances in the solution. He states that common salt which he finds frequently recommended gives negative results.

Hitchcock and Zimmerman (3) tested some fifty-one chemicals in an effort to find one, or a mixture of several which would give consistently beneficial results. Preliminary experiments were first run to determine decidedly injurious concentrations and then each chemical was used in concentrations ranging from 0.01% to 0.000001%. Their results are definitely stated: "None of the compounds was noticeably effective in prolonging the life of cut flowers used in these experiments." The flowers treated were aster, coreopsis, gladiolus, phlox, delphinium and dahlia. Cosmos, snapdragon and chrysanthemum were subjected to aspirin treatments of various concentrations and were in no way benefited. The authors found that the flowers which had the best keeping qualities were those which lost the greatest amounts of water by transpiration, although many of the chemicals reduced transpiration rate. These men came to the conclusion that methods involving variation in humidity and temperature offered more hope of success than chemical methods and their work on these factors is discussed under storage.

Ratsek (17) takes the view that bacterial action is an important factor and he studied methods of preventing it. His

work was done with copper containers in which the active principle was copper oxide or copper metal. He uses ten to twenty flowers in each container to reduce the effect of individual flower variation. In regard to keeping time the number of days is given up to the time when one-half the flowers in a container were ready to be discarded. He demonstrated that the flowers tested could be divided into three groups: (1) those flowers benefited by the presence of copper such as pansies, carnations, asters, chrysanthemums, peonies, snapdragons and delphiniums; (2) those flowers not affected by the presence of copper such as roses, sweet peas, tulips, narcissi and gladioli; (3) those flowers definitely injured by the presence of copper--the cyclamens. He recorded the amount of water taken up by the flowers in the copper and check (glass) containers and showed that those flowers which lasted best took up the greatest amounts of water. He only gives the total amount taken up by each type of flower and while this is interesting it would have been much more useful to have recorded the day to day absorption for both the checks and the treated flowers. Ratsek suggests that the copper inhibits the growth of bacteria in the water which clog the conducting elements and prevent water reaching the flower head. The reason why some flowers are not benefited by presence of copper is that these have large conducting vessels which do not easily become clogged with bacteria. Other workers do not consider bacterial action a serious trouble.

Laurie (6) confirmed Ratsek's results with copper except that he found carnations injured by the presence of copper. He

recommends three chemicals as effective in improving the keeping qualities of cut flowers: hydrazine sulphate, phloroglucinol and resorcinol. He gives four formulae:

1. Hydrazine sulphate and manganese sulphate for roses.
2. Boric acid for carnations.
3. 10% to 15% sucrose for asters.
4. Commercial alum, sodium hypochlorite and iron oxide for roses.

These recommendations are not supported by any published experimental data. It might be noted that commercial Floralife contains three of his chemicals: hydrazine sulphate, sucrose and alum.

Neff, although primarily interested in storage problems, has several papers dealing with chemical treatments (14, 15). He worked with roses and in preliminary tests found that roses stored with their stems in Floralife, to which had been added two and one-half times the sugar recommended, gave the best results as to color and keeping qualities. Roses stored in the solution for one hundred and eighty-five hours not only had fresh colored turgid petals but lasted longer under room conditions than freshly cut flowers. It might be noted that the flowers, although treated with the chemical solution in storage, were placed in water under room conditions, a variation of the usual chemical procedure. The effect of the chemicals was modified by the presence of light as those flowers stored in the dark showed some tendency to a bluing of the petals. In further work with a number of different solutions Neff found that solutions containing water, sucrose and a salt of one of the heavy

metals such as aluminium sulphate or iron sulphate aided in improving the keeping qualities of the roses.

It appears from a review of the literature that early workers thought the chemical approach most promising, while later workers have tended to emphasize physical methods. However, in the most recent work done by Neff a combination of the two approaches is utilized.

Attention might be drawn to the fact that methods of cultivation are known to influence the duration of cut flowers. Tincker (22) states, in his review of the subject of improving the keeping qualities of cut flowers, that under greenhouse conditions over or under watering, extremes in temperature, excessive forcing and inadequate shading of certain flowers all tend to curtail the life of the flowers. The level of soil fertility and the relative amounts of the various nutrients available to the plant also play an important part. The technique of cutting, packing and transporting for market is important and varies for different kinds of flowers.

Since this thesis is not concerned primarily with the processes of respiration or transpiration the extensive literature on these subjects is not reviewed. However Miller (10) has given comprehensive discussions of these subjects and recorded an extensive bibliography, and Stiles and Leach (20) have given an excellent account of respiration.

EXPERIMENTS - PART I

These experiments were undertaken to discover a chemical or chemicals which induced a marked response from a given flower. Since several workers have suggested that an effective chemical should affect transpiration in some way it was decided that transpiration rate should be recorded. The recording of water loss would also serve to show if physiological processes are affected by the different chemicals.

Methods

Setup for Transpiration Measurements

Erlenmeyer flasks (200 cc.) were used as flower containers. Each flask was fitted with a cork stopper through which the flower was inserted until the end of the stem just touched the bottom and thus was deep in the solution. The flowers were set up one to a container and each one tagged, e.g., no. 1. A mixture of paraffin - 20 gm., beeswax - 10 gm., and cocoa butter - 20 gm., which was easily worked yet did not melt under any of the temperatures experienced, was used to seal the openings and make the setup airtight. With checks, that is flasks with a piece of glass tubing substituting for the flower, it was found that the setup was airtight, therefore loss in weight from day to day was equal to water transpired by the flowers. At the beginning of an experiment each flower's stem was recut; it was then weighed and placed in the container, after which the weight

of the whole setup was recorded. The setup was weighed each day and the water transpired was obtained by subtracting the weight of the setup from the weight recorded for it the previous day. The water loss per twenty-four hours was divided by the original wet weight of the flower to give transpiration rate. This rate was then expressed as water loss in grams per gram initial wet weight of tissue in twenty-four hours.

Longevity of the Flower

The length of life of each flower was noted and day to day notes were taken on flower appearance as an aid in the final decision on the chemical used. It is very difficult to determine just when a flower is ready to be discarded and this was one of the first and continuous difficulties experienced in this work. Many workers fail to give precise details on this point, yet it is very important as all recommendations as to whether a chemical improves the keeping qualities of a flower depend on it. For example, Hitchcock and Zimmerman (3) say that they took the final data for each treatment when the majority of flowers remained in good condition, however they do not state how many flowers they used, how they were set up or on what criteria they considered them ready to discard. When is a flower ready to be discarded? Obviously this will depend on the judgment of the person concerned and for this reason details should be clearly described. In this work the flowers were discarded on the following criteria: petals falling, petals discolored or bleached, petals and leaves (when present) wilted, odor lost or a stale smell about the flower. Except for the first point which was sufficient in itself, one or more of these criteria were considered in the

decision.

The treated flowers were placed immediately in chemical solution while the checks were held in double distilled water under the same conditions. The water for the checks and for the chemical solutions was distilled first in a copper still and then in a glass still to make certain it contained no traces of other chemicals as it has been shown that extremely small amounts of some substances affect living tissues. In each experiment flowers were used which appeared similar in all respects.

Results

Experiment I

Material: One dozen roses in the loose bud stage.

Chemicals: Floralife (alum, hydrazine sulphate, sucrose, plus an undetermined alcohol soluble substance).

1 gram in 30.5 cc.

Average temperature: 24.4°C.

Conditions: Flowers placed in solution immediately when received. Each flask contained 130 cc. of solution and held one flower. Stems not recut.

Results: The results are shown in Table 1 and graphically in Figures 1, 2 and 3. From Figure 1 it can be seen that in general the average transpiration rates of the flowers in Floralife tended to be lower than those of the check flowers. In the case of the flowers which lasted well it appeared that the transpiration rate increased sharply at first and then tended to level off (Figure 2);

with those flowers that did not last (Figure 3) there was not this final levelling off; instead the transpiration rate dropped rapidly after the third day. The length of life of each flower is shown in the table; they lasted one day longer than the transpiration figures recorded as with this method it is not possible to measure transpiration until twenty-four hours have passed.

Experiment 2

Material: Cultivated geranium blooms cut from potted plants.

Chemicals: Floralife, 1 gram in 30.5 cc. distilled water.

Average temperature: 25.6°C.

Conditions: Geraniums cut from the plants and immediately placed in water or solution.

Results: The actual results are shown in Table 2 and graphically in Figure 2, upper graph. The experiment ran nine days and at that time the majority of blooms were dead. The fact that each bloom consists of many small individual flowers which matured at different times introduces an error as it is difficult to determine when the flower is ready to be discarded. There were no differences between the length of life of the flowers in chemical and the checks. However, as can be seen from Figure 2, the transpiration rate was markedly reduced by the chemical solution.

Table 1. Results, Experiment 1

Flow- er no.	Day 1		Day 2		Day 3		Day 4		Day 5		Day 6		Day 7		Av. Days tr. # flower rate# lasted
	Water loss*	Tr. rate**	Water loss	Tr. rate	Water loss	Tr. rate	Water loss	Tr. rate	Water loss	Tr. rate	Water loss	Tr. rate	Water loss	Tr. rate	
	gm.	gm.	gm.	gm.	gm.	gm.	gm.	gm.	gm.	gm.	gm.	gm.	gm.	gm.	
1	4.5	0.36	11.0	0.88	9.2	0.73	8.8	0.70	9.1	0.72	7.2	0.57	7.2	0.57	0.65
2	0.1	0.009	17.1	1.66	11.7	1.14	11.5	0.85	10.7	0.98	6.3	0.69	--	--	0.89
3	17.4	0.80	20.8	0.96	15.9	0.73	--	--	--	--	--	--	--	--	0.83
4	14.8	0.61	30.3	1.25	17.6	0.72	--	--	--	--	--	--	--	--	0.96
5	4.1	0.26	23.1	0.51	10.6	0.73	--	--	--	--	--	--	--	--	0.83
6	4.8	0.49	12.8	1.32	11.2	1.15	8.1	0.83	8.1	0.83	8.1	0.83	--	--	0.91
7	7.1	0.41	37.4	0.87	19.7	0.76	--	--	--	--	--	--	--	--	0.68
8	5.2	0.44	28.5	2.41	13.5	1.14	--	--	--	--	--	--	--	--	1.33
9	8.0	0.51	40.5	2.75	17.2	1.09	--	--	--	--	--	--	--	--	1.45
10	11.6	0.68	33.7	2.00	14.8	0.88	--	--	--	--	--	--	--	--	1.18
11	16.4	0.79	37.6	1.83	14.6	0.70	--	--	--	--	--	--	--	--	1.10
12	13.6	0.74	30.5	1.66	5.7	0.31	--	--	--	--	--	--	--	--	0.90

1 - 6 flowers in Floralife, 1 gm. in 30.5 cc. H₂O
7 -12, checks

* Water loss in grams per twenty-four hours.

**Water loss in grams per gram original wet weight of tissue.

Each figure represents the average transpiration rate of a given flower during its life under the conditions of the experiment.

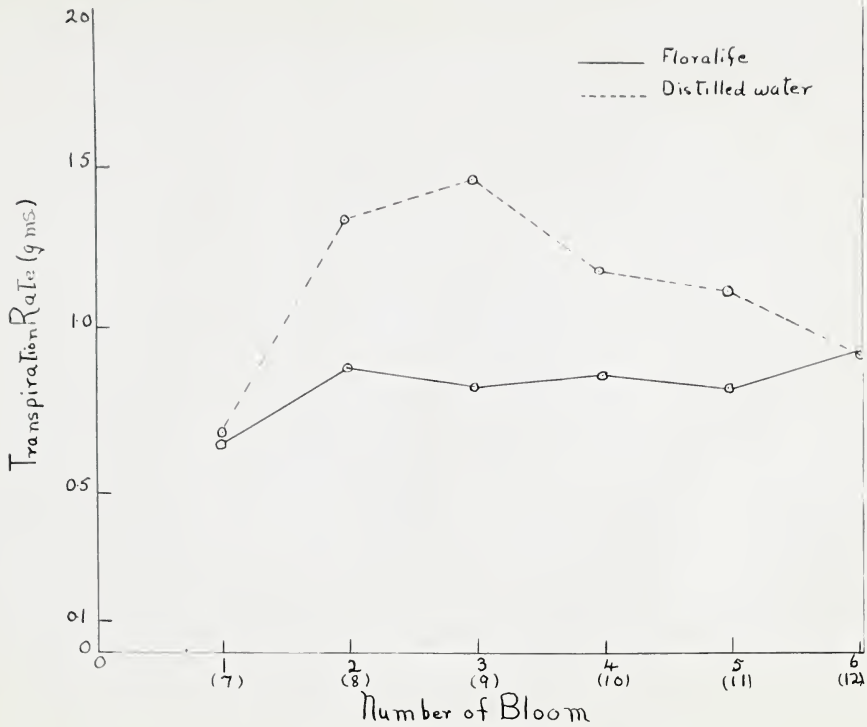


Figure 1

The effect of Floralife on the transpiration of roses.

Note: Each point represents the average transpiration rate of one flower during its life (from the beginning of the experiment until it was discarded).

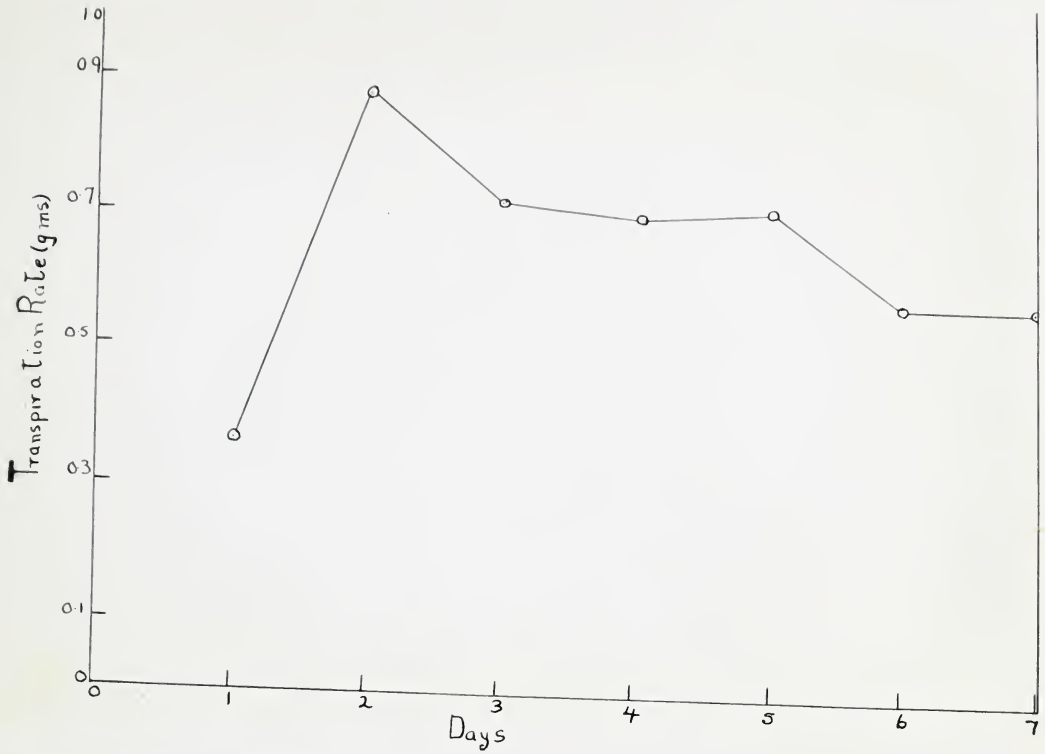


Figure 2

The daily transpiration rate of one of the roses in Floralife which lasted 4 days longer than the checks.

Note: Each point represents the transpiration rate during a 24-hour period.

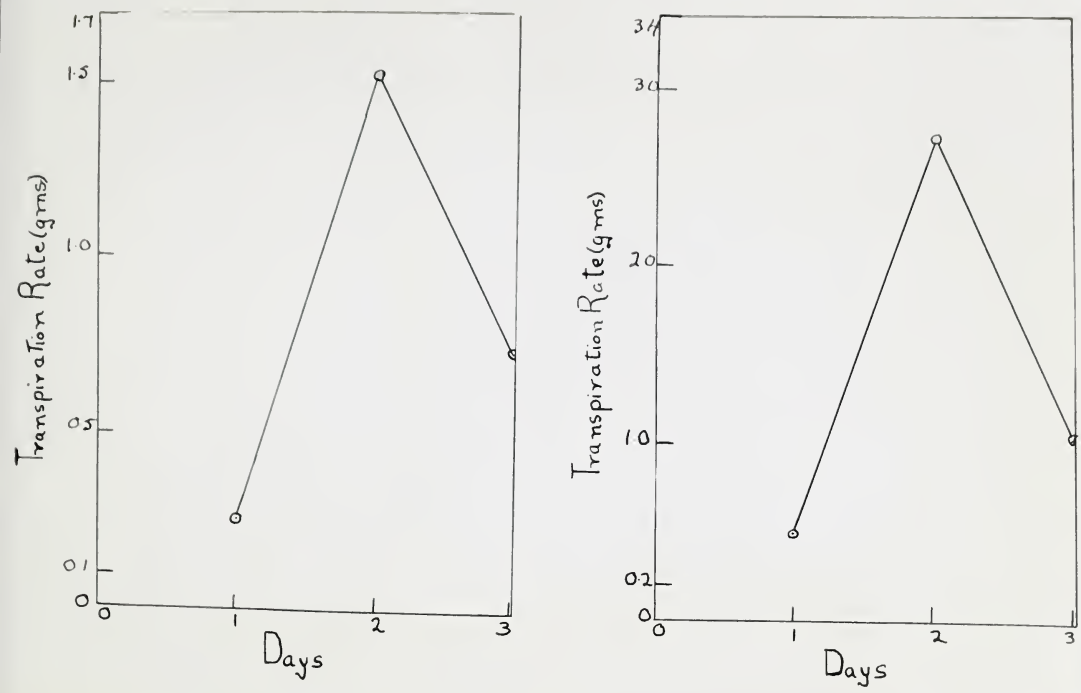


Figure 3

The daily transpiration rates of typical short-lived flowers.

Note: On the left is the graph of a short-lived treated flower (in Floralife), on the right a graph of a check flower.

Table 2. Results, Experiment 2

Flow- er no.	Day 1		Day 2		Day 3		Day 4		Day 5		Day 6		Day 7		Day 8		Av. tr. rate
	Water Tr. loss rate	gm.	Water Tr. loss rate	gm.	Water Tr. loss rate	gm.	Water Tr. loss rate	gm.	Water Tr. loss rate	gm.	Water Tr. loss rate	gm.	Water Tr. loss rate	gm.	Water Tr. loss rate	gm.	
1	3.3	0.29	2.2	0.19	1.3	0.11	1.3	0.11	1.4	0.12	0.9	0.07	0.8	0.07	1.0	0.08	0.13
2	4.7	0.31	2.3	0.16	2.6	0.17	1.8	0.12	1.6	0.10	1.1	0.07	0.8	0.05	1.2	0.08	0.13
3	3.8	0.34	2.6	0.23	0.9	0.08	1.1	0.10	1.1	0.10	2.1	0.19	0.9	0.08	1.0	0.09	0.15
4	4.5	0.41	3.1	0.28	1.3	0.12	1.3	0.12	1.3	0.12	0.9	0.08	1.1	0.10	1.2	0.11	0.16
5	3.4	0.30	2.4	0.21	1.0	0.09	1.1	0.09	0.9	0.08	0.9	0.08	0.6	0.05	1.0	0.09	0.12
6	7.7	0.42	4.4	0.28	1.9	0.12	1.8	0.11	1.5	0.09	1.6	0.10	1.0	0.07	1.5	0.09	0.16
7	5.6	0.38	5.2	0.35	1.2	0.08	1.3	0.08	1.5	0.10	1.0	0.10	0.9	0.06	1.2	0.08	0.15
8	5.5	0.34	2.7	0.16	1.7	0.10	1.7	0.10	1.1	0.06	1.1	0.06	1.1	0.06	1.0	0.06	0.11
9	6.2	0.54	3.5	0.30	1.2	0.10	1.4	0.12	1.0	0.09	0.9	0.07	1.0	0.08	1.0	0.08	0.17
10	2.5	0.19	1.5	0.11	1.1	0.08	1.0	0.07	0.6	0.04	0.5	0.03	0.5	0.03	0.5	0.03	0.07
11	1.8	0.16	1.2	0.10	0.7	0.06	0.8	0.07	0.6	0.05	0.4	0.03	0.5	0.04	0.5	0.04	0.06
12	1.6	0.18	1.0	0.11	0.6	0.08	0.7	0.07	1.5	0.16	0.0	0.0	0.2	0.02	0.7	0.07	0.03
13	1.5	0.15	1.0	0.10	0.7	0.07	0.5	0.05	0.4	0.04	0.3	0.03	0.6	0.06	0.5	0.05	0.06
14	1.6	0.16	0.9	0.09	0.7	0.07	0.6	0.06	0.3	0.03	0.6	0.06	0.2	0.02	0.5	0.05	0.06
15	2.9	0.21	1.3	0.09	0.8	0.05	0.7	0.05	0.7	0.05	0.3	0.02	0.4	0.02	0.6	0.04	0.06
16	2.6	0.29	1.4	0.15	0.8	0.09	0.9	0.10	0.5	0.05	0.7	0.07	0.4	0.04	0.7	0.07	0.11
17	2.5	0.27	1.1	0.12	0.7	0.07	0.6	0.06	0.4	0.04	0.6	0.06	0.4	0.04	0.4	0.04	0.08
18	2.2	0.17	1.5	0.12	1.0	0.08	0.9	0.07	1.1	0.08	0.5	0.03	0.5	0.03	0.7	0.05	0.07

Note: All flowers lasted 9 days.

1 - 9, check

10 - 18, chemical (Floralife) 1 gm. in 30.5 cc. H₂O

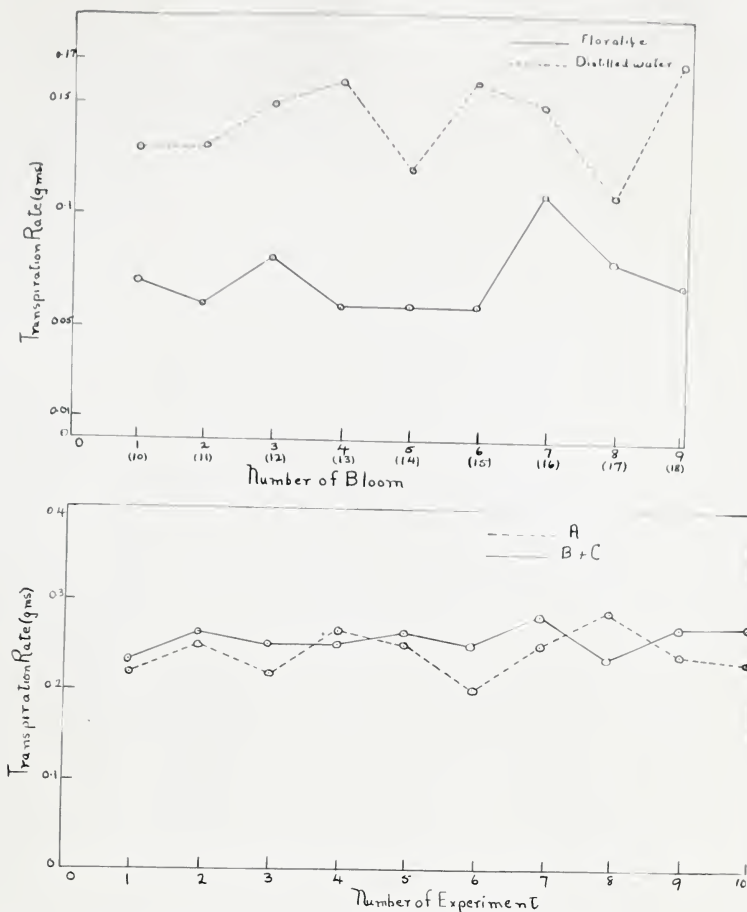


Figure 4

(1) The effect of Floralife on transpiration of geranium blooms (upper graph).

Note: Each point represents the average transpiration rate of one flower during its life (from the beginning of the experiment until it was discarded).

(2) The transpiration results from main experiment with roses (lower graph).

Note: Each point on the broken line represents the average transpiration rate of roses in water, each point on the continuous line the average transpiration rate of roses in chemical solution.

Experiment 3

Material: Lupins.

Chemicals: Calcium nitrate solutions of three concentrations: 1 gram per 78.8 cc., one gram per 157.7 cc. and 1 gram per 315.4 cc. distilled water.

Average temperature: 24°C.

Conditions: The flowers were plunged in the solutions immediately after cutting from the plants and held there for four hours. They were then transferred to tap water and their behavior noted. Checks were held in tap water for the same period of time. This treatment is the one prescribed to prevent "topple" of lupins or collapse of the stem under room conditions. It might be noted that holding the flowers in chemicals and then transferring to water is not the usual method of chemical treatment.

Results: The actual results are shown in Table 3. The keeping qualities were not affected by the chemical and it did not prevent the collapse of the stems although this condition was not found to be serious in this experiment or in others where no figures were recorded. It can be seen from the table that transpiration rate is not affected by the calcium nitrate. The results were not presented graphically but they would give a graph like the one shown in Figure 5 on the right.

Experiment 4

Material: Carnations, three-quarters opened.

Chemicals: Floralife, same concentration as previous experiments.

Table 3. Results, Experiment 3

Flower no.	Day 1		Day 2		Day 3		Day 4		Av. tr. rate	Days flower lasted
	Water loss	Tr. rate	Water loss	Tr. rate	Water loss	Tr. rate	Water loss	Tr. rate		
	gm.	gm.	gm.	gm.	gm.	gm.	gm.	gm.	gm.	gm.
1	21.5	1.2	25.4	1.4	17.5	1.0	11.6	0.6	1.00	5
2	13.2	0.8	15.3	0.9	8.2	0.5	6.0	0.3	0.62	5
3	15.0	0.9	11.3	0.6	5.5	0.3	--	--	0.60	4
4	14.1	0.9	19.9	1.2	11.2	0.7	--	--	0.93	4
5	16.9	1.0	18.1	1.1	6.8	0.4	--	--	0.83	4
6	12.5	0.7	15.8	0.9	8.9	0.5	7.6	0.4	0.62	5
7	11.1	0.7	16.9	1.2	9.1	0.6	--	--	0.83	4
8	15.2	0.9	18.2	1.1	7.0	0.4	--	--	0.80	4
9	10.3	0.6	16.0	0.9	9.7	0.6	--	--	0.70	4
10	10.1	0.6	14.1	0.9	8.6	0.5	--	--	0.66	4
11	17.4	1.1	23.1	1.4	13.8	0.8	--	--	1.10	4
12	14.0	0.8	16.8	1.0	18.2	1.1	--	--	0.96	4
13	16.0	1.1	14.3	1.0	2.6	0.11	--	--	0.73	4
14	13.0	1.1	16.2	1.4	7.5	0.6	--	--	1.00	4
15	12.7	0.7	15.5	0.9	9.4	0.5	--	--	0.70	4
16	10.8	0.8	15.3	1.2	8.5	0.7	5.7	0.4	0.77	5
17	14.1	1.0	17.6	1.2	8.2	0.5	--	--	0.90	4
18	14.4	1.0	15.0	1.0	4.8	0.3	--	--	0.76	4
19	10.0	0.8	13.9	1.1	7.8	0.6	4.8	0.4	0.96	5

1 - 5 Check flowers in distilled water

6 -10 $\text{Ca}(\text{NO}_3)_2$, 1 gm. in 78.8 cc. water

11-15 " 1 " " 157.7 cc. "

12-19 " 1 " " 315.4 cc. "

Table 2. Results of the analysis of variance

Source of variation	D.F.	Between groups		Within groups		Total		F		Significance level
		Sum of squares	Mean square	Sum of squares	Mean square	Sum of squares	Mean square	Sum of squares	Mean square	
1. Between groups	1	10.1	10.1	10.1	10.1	10.1	10.1	10.1	10.1	0.1
2. Within groups	10	10.1	1.01	10.1	1.01	10.1	1.01	10.1	1.01	0.1
3. Total	11	20.2	1.84	20.2	1.84	20.2	1.84	20.2	1.84	0.1
4. Between groups	1	10.1	10.1	10.1	10.1	10.1	10.1	10.1	10.1	0.1
5. Within groups	10	10.1	1.01	10.1	1.01	10.1	1.01	10.1	1.01	0.1
6. Total	11	20.2	1.84	20.2	1.84	20.2	1.84	20.2	1.84	0.1
7. Between groups	1	10.1	10.1	10.1	10.1	10.1	10.1	10.1	10.1	0.1
8. Within groups	10	10.1	1.01	10.1	1.01	10.1	1.01	10.1	1.01	0.1
9. Total	11	20.2	1.84	20.2	1.84	20.2	1.84	20.2	1.84	0.1
10. Between groups	1	10.1	10.1	10.1	10.1	10.1	10.1	10.1	10.1	0.1
11. Within groups	10	10.1	1.01	10.1	1.01	10.1	1.01	10.1	1.01	0.1
12. Total	11	20.2	1.84	20.2	1.84	20.2	1.84	20.2	1.84	0.1
13. Between groups	1	10.1	10.1	10.1	10.1	10.1	10.1	10.1	10.1	0.1
14. Within groups	10	10.1	1.01	10.1	1.01	10.1	1.01	10.1	1.01	0.1
15. Total	11	20.2	1.84	20.2	1.84	20.2	1.84	20.2	1.84	0.1
16. Between groups	1	10.1	10.1	10.1	10.1	10.1	10.1	10.1	10.1	0.1
17. Within groups	10	10.1	1.01	10.1	1.01	10.1	1.01	10.1	1.01	0.1
18. Total	11	20.2	1.84	20.2	1.84	20.2	1.84	20.2	1.84	0.1
19. Between groups	1	10.1	10.1	10.1	10.1	10.1	10.1	10.1	10.1	0.1
20. Within groups	10	10.1	1.01	10.1	1.01	10.1	1.01	10.1	1.01	0.1
21. Total	11	20.2	1.84	20.2	1.84	20.2	1.84	20.2	1.84	0.1
22. Between groups	1	10.1	10.1	10.1	10.1	10.1	10.1	10.1	10.1	0.1
23. Within groups	10	10.1	1.01	10.1	1.01	10.1	1.01	10.1	1.01	0.1
24. Total	11	20.2	1.84	20.2	1.84	20.2	1.84	20.2	1.84	0.1
25. Between groups	1	10.1	10.1	10.1	10.1	10.1	10.1	10.1	10.1	0.1
26. Within groups	10	10.1	1.01	10.1	1.01	10.1	1.01	10.1	1.01	0.1
27. Total	11	20.2	1.84	20.2	1.84	20.2	1.84	20.2	1.84	0.1
28. Between groups	1	10.1	10.1	10.1	10.1	10.1	10.1	10.1	10.1	0.1
29. Within groups	10	10.1	1.01	10.1	1.01	10.1	1.01	10.1	1.01	0.1
30. Total	11	20.2	1.84	20.2	1.84	20.2	1.84	20.2	1.84	0.1

Source of variation: Between groups, Within groups, Total

Sum of squares: 10.1, 10.1, 20.2

Mean square: 10.1, 1.01, 1.84

F: 10.1, 1.01, 1.84

Average temperature: 26°C.

Conditions: Flowers cut and placed immediately in solution.

Results: The results are presented in Table 4 and graphically in the left-hand graph, Figure 5. The carnations lasted one day longer in Floralife than in water, although there was considerable individual variation. From the graph it can be seen that transpiration was reduced to some extent by the chemical solution though not markedly so, as in experiment 2 for example.

Experiment 5

Material: Carnations fully opened.

Chemicals: Sucrose, 1 gram in 181.9 cc. of water.

Average temperature: 26°C.

Conditions: Carnations cut and placed immediately in sucrose solution.

Results: The actual results are shown in Table 5 and graphically in Figure 5, right-hand graph. The sucrose made no definite improvement in keeping qualities although two of the flowers in sucrose lasted several days longer than the others in the experiment. The transpiration rate was not affected by the presence of sucrose in the water, as can be seen in the graph.

Experiment 6

Material: Small white daisies (genus *Anthemis*), full open.

Chemicals: Sucrose (1 gram per 181.9 cc.) hydrazine sulphate and alum (1 gram per 94.6 cc.) and Floralife (1 gram

Table 4. Results, Experiment 4

Flow- er no.	Day 1		Day 2		Day 3		Day 4		Day 5		Day 6		Day 7		Day 8		Day 9		Av. tr. rate
	Water loss	Tr. rate	Water loss	Tr. rate	Water loss	Tr. rate	Water loss	Tr. rate	Water loss	Tr. rate	Water loss	Tr. rate	Water loss	Tr. rate	Water loss	Tr. rate	Water loss	Tr. rate	
	gm.	gm.	gm.	gm.	gm.	gm.	gm.	gm.	gm.	gm.	gm.	gm.	gm.	gm.	gm.	gm.	gm.	gm.	
1	1.4	0.20	2.1	0.31	2.0	0.29	1.1	0.17	1.5	0.22	2.4	0.30	2.2	0.32	2.6	0.38	2.7	0.40	0.29
2	1.9	0.27	2.7	0.39	2.2	0.31	1.4	0.20	1.8	0.26	2.1	0.31	1.1	0.15	0.3	0.04	0.6	0.05	0.22
3	2.2	0.30	3.1	0.40	2.7	0.30	1.5	0.20	1.9	0.20	2.6	0.30	2.0	0.20	2.1	0.20	2.2	0.30	0.26
4	1.4	0.22	2.1	0.33	1.8	0.28	1.0	0.15	1.2	0.21	2.3	0.35	2.4	0.36	1.4	0.21	1.4	0.21	0.26
5	1.3	0.20	1.5	0.23	1.3	0.20	1.0	0.15	1.2	0.21	2.3	0.35	2.4	0.36	1.4	0.21	1.4	0.21	0.26
6	2.1	0.27	2.8	0.36	2.4	0.31	1.4	0.18	2.0	0.25	2.4	0.31	2.2	0.28	2.4	0.31	2.4	0.31	0.28
7	2.0	0.25	2.1	0.26	1.7	0.21	1.2	0.12	1.3	0.16	1.7	0.24	1.6	0.22	2.4	0.30	2.5	0.30	0.22
8	1.6	0.36	2.4	0.40	2.3	0.38	1.7	0.28	2.1	0.35	2.9	0.45	2.9	0.45	3.6	0.60	3.6	0.60	0.43
9	1.7	0.28	3.4	0.36	3.8	0.35	2.5	0.25	2.8	0.29	3.7	0.39	3.2	0.34	3.8	0.40	3.8	0.40	0.35
10	1.2	0.20	2.0	0.34	1.9	0.32	1.2	0.20	1.9	0.32	2.5	0.40	2.0	0.34	3.1	0.53	3.2	0.55	0.36

1 - 5, flowers in Floralife - 1 gm. in 30.5 cc. H₂O
6 -10, checks

Note: The flowers in chemical lasted 11 days, those in distilled water 10 days.

Table 1. Summary of data for the first 1000 cases.

Case No.		Age (yr)		Sex		Race		Religion		Total
1	2	3	4	5	6	7	8	9	10	
1	1001	25	25	M	M	W	W	C	C	1
2	1002	26	26	F	F	W	W	C	C	1
3	1003	27	27	M	M	W	W	C	C	1
4	1004	28	28	F	F	W	W	C	C	1
5	1005	29	29	M	M	W	W	C	C	1
6	1006	30	30	F	F	W	W	C	C	1
7	1007	31	31	M	M	W	W	C	C	1
8	1008	32	32	F	F	W	W	C	C	1
9	1009	33	33	M	M	W	W	C	C	1
10	1010	34	34	F	F	W	W	C	C	1
11	1011	35	35	M	M	W	W	C	C	1
12	1012	36	36	F	F	W	W	C	C	1
13	1013	37	37	M	M	W	W	C	C	1
14	1014	38	38	F	F	W	W	C	C	1
15	1015	39	39	M	M	W	W	C	C	1
16	1016	40	40	F	F	W	W	C	C	1
17	1017	41	41	M	M	W	W	C	C	1
18	1018	42	42	F	F	W	W	C	C	1
19	1019	43	43	M	M	W	W	C	C	1
20	1020	44	44	F	F	W	W	C	C	1
21	1021	45	45	M	M	W	W	C	C	1
22	1022	46	46	F	F	W	W	C	C	1
23	1023	47	47	M	M	W	W	C	C	1
24	1024	48	48	F	F	W	W	C	C	1
25	1025	49	49	M	M	W	W	C	C	1
26	1026	50	50	F	F	W	W	C	C	1
27	1027	51	51	M	M	W	W	C	C	1
28	1028	52	52	F	F	W	W	C	C	1
29	1029	53	53	M	M	W	W	C	C	1
30	1030	54	54	F	F	W	W	C	C	1
31	1031	55	55	M	M	W	W	C	C	1
32	1032	56	56	F	F	W	W	C	C	1
33	1033	57	57	M	M	W	W	C	C	1
34	1034	58	58	F	F	W	W	C	C	1
35	1035	59	59	M	M	W	W	C	C	1
36	1036	60	60	F	F	W	W	C	C	1
37	1037	61	61	M	M	W	W	C	C	1
38	1038	62	62	F	F	W	W	C	C	1
39	1039	63	63	M	M	W	W	C	C	1
40	1040	64	64	F	F	W	W	C	C	1
41	1041	65	65	M	M	W	W	C	C	1
42	1042	66	66	F	F	W	W	C	C	1
43	1043	67	67	M	M	W	W	C	C	1
44	1044	68	68	F	F	W	W	C	C	1
45	1045	69	69	M	M	W	W	C	C	1
46	1046	70	70	F	F	W	W	C	C	1
47	1047	71	71	M	M	W	W	C	C	1
48	1048	72	72	F	F	W	W	C	C	1
49	1049	73	73	M	M	W	W	C	C	1
50	1050	74	74	F	F	W	W	C	C	1
51	1051	75	75	M	M	W	W	C	C	1
52	1052	76	76	F	F	W	W	C	C	1
53	1053	77	77	M	M	W	W	C	C	1
54	1054	78	78	F	F	W	W	C	C	1
55	1055	79	79	M	M	W	W	C	C	1
56	1056	80	80	F	F	W	W	C	C	1
57	1057	81	81	M	M	W	W	C	C	1
58	1058	82	82	F	F	W	W	C	C	1
59	1059	83	83	M	M	W	W	C	C	1
60	1060	84	84	F	F	W	W	C	C	1
61	1061	85	85	M	M	W	W	C	C	1
62	1062	86	86	F	F	W	W	C	C	1
63	1063	87	87	M	M	W	W	C	C	1
64	1064	88	88	F	F	W	W	C	C	1
65	1065	89	89	M	M	W	W	C	C	1
66	1066	90	90	F	F	W	W	C	C	1
67	1067	91	91	M	M	W	W	C	C	1
68	1068	92	92	F	F	W	W	C	C	1
69	1069	93	93	M	M	W	W	C	C	1
70	1070	94	94	F	F	W	W	C	C	1
71	1071	95	95	M	M	W	W	C	C	1
72	1072	96	96	F	F	W	W	C	C	1
73	1073	97	97	M	M	W	W	C	C	1
74	1074	98	98	F	F	W	W	C	C	1
75	1075	99	99	M	M	W	W	C	C	1
76	1076	100	100	F	F	W	W	C	C	1

Table 2. Summary of data for the next 1000 cases.

Table 3. Summary of data for the last 1000 cases.

Table 5. Results, Experiment 5

Flower no.	Day 1		Day 2		Day 3		Day 4		Day 5		iv. tr. rate
	Water loss	Tr. rate	Water loss	Tr. rate	Water loss	Tr. rate	Water loss	Tr. rate	Water loss	Tr. rate	
	gm.	gm.	gm.	gm.	gm.	gm.	gm.	gm.	gm.	gm.	
1	1.9	0.30	2.2	0.35	2.5	0.41	1.4	0.20	2.4	0.30	0.31
2	1.6	0.26	2.2	0.36	2.9	0.48	1.4	0.23	2.8	0.46	0.35
3	1.5	0.26	1.4	0.24	1.9	0.33	0.8	0.14	1.0	0.17	0.22
4	1.5	0.28	1.9	0.36	2.1	0.40	1.2	0.23	2.1	0.40	0.33
5	1.3	0.27	1.2	0.25	1.5	0.31	0.7	0.14	1.5	0.31	0.25
6	1.4	0.21	1.3	0.20	1.5	0.23	0.9	0.12	1.6	0.24	0.20
7	2.7	0.44	3.0	0.54	3.3	0.54	2.1	0.34	0.9	0.14	0.40
8	1.8	0.35	2.1	0.40	2.3	0.28	1.5	0.28	0.9	0.17	0.29
9	1.2	0.18	1.3	0.20	1.4	0.21	0.7	0.10	1.4	0.21	0.18
10	2.3	0.37	2.2	0.36	2.7	0.44	1.2	0.19	2.6	0.42	0.35

1-5, check flowers
6-10, sucrose solution - 1 gm. in 181.9 cc. water

Note: No difference in length of life between flowers in solution and checks.

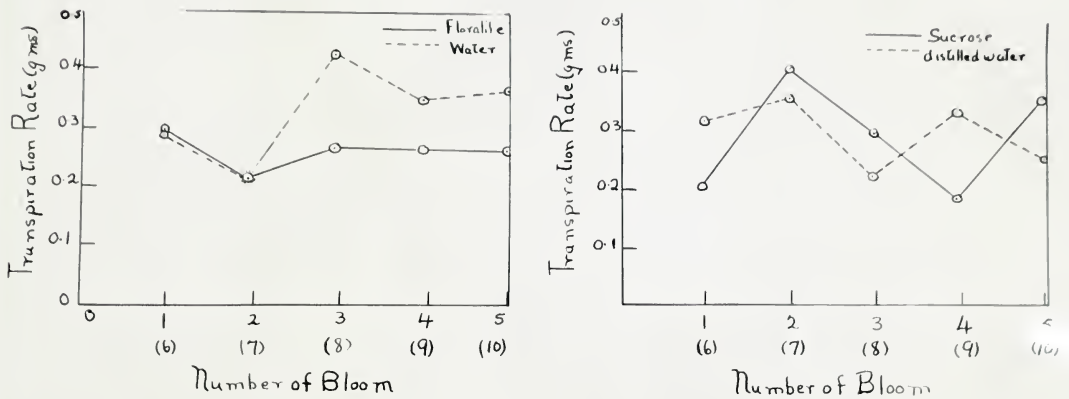


Figure 5

(1) The effect of Floralife on transpiration of carnations - on the left.

(2) The effect of sucrose on transpiration of carnations - on the right.

Note: Each point represents the average transpiration rate of one flower during its life (from the beginning of the experiment until it was discarded).

per 30.5 cc. distilled water).

Average temperature: 26°C.

Conditions: Flowers cut and placed at once in solution.

Results: The actual results are shown in Table 6. None of the chemical treatments was effective in prolonging the lives of the treated flowers beyond that of the checks; the hydrazine^{sulphate} and alum showed some tendency to shorten the life of the flowers. The transpiration rates of the flowers in Floralife were higher than those in the other solutions and in distilled water.

Discussion of Results

In these experiments a number of chemicals which had been reported to improve the keeping qualities of cut flowers were given at least one trial and at the same time transpiration measurements were taken. As well as the chemicals mentioned the following were tested: thymol, copper metal, copper sulphate, lactic acid, resorcinol, phloroglucinol, aluminium sulphate, calcium chloride and camphor. A range of concentrations was used for each one but only detrimental effects were obtained, with the exception of the aluminium sulphate which effected a slight improvement.

It is recognized that one or two experiments do not present sufficient evidence on which to draw conclusions about a given chemical's effect on a species of flower, but these experiments were carried out for two reasons: first, to find a chemical which definitely affected the keeping qualities of a given

Table 6. Results, Experiment 6

	Day 1		Day 2		Day 3		Day 4		Day 5		Day 6		Day 7		Day 8		Day 9		Day 10		Day 11		Day 12		Day 13		Av. tr. rate	Days flowers lasted
Flower no.	Water loss	Tr. rate	Water loss	Tr. rate	Water loss	Tr. rate	Water loss	Tr. rate	Water loss	Tr. rate	Water loss	Tr. rate	Water loss	Tr. rate	Water loss	Tr. rate	Water loss	Tr. rate	Water loss	Tr. rate	Water loss	Tr. rate	Water loss	Tr. rate	Water loss	Tr. rate		
	gm.	gm.	gm.	gm.	gm.	gm.	gm.	gm.	gm.	gm.	gm.	gm.	gm.	gm.	gm.	gm.	gm.	gm.	gm.	gm.	gm.	gm.	gm.	gm.	gm.	gm.		
1	1.1	0.91	1.1	0.91	0.9	0.75	0.4	0.33	0.6	0.50	0.5	0.41	0.5	0.41	1.3	1.00	0.5	0.41	0.4	0.33	0.4	0.33	--	--	--	--	0.51	12
2	0.7	0.43	1.2	0.75	1.5	0.93	0.7	0.43	0.9	0.56	0.9	0.56	0.9	0.56	0.7	0.43	1.0	0.62	1.1	0.68	1.2	0.75	--	--	--	--	0.60	12
3	1.5	0.78	0.6	0.31	0.9	0.47	0.4	0.21	0.8	0.42	0.8	0.42	0.8	0.42	0.7	0.36	0.6	0.31	0.8	0.42	--	--	--	--	--	--	0.40	11
4	1.3	0.72	0.8	0.44	1.2	0.66	0.4	0.22	0.6	0.33	0.7	0.38	0.7	0.38	0.6	0.33	--	--	--	--	--	--	--	--	--	--	0.43	9
5	1.1	0.57	0.9	0.47	0.9	0.47	0.7	0.36	0.9	0.47	0.9	0.47	0.9	0.47	1.2	0.63	--	--	--	--	--	--	--	--	--	--	0.48	9
6	1.5	0.78	1.0	0.52	1.1	0.57	0.7	0.36	0.8	0.42	0.5	0.25	0.5	0.25	1.2	0.63	0.9	0.47	--	--	--	--	--	--	--	--	0.47	11
7	1.0	1.00	0.6	0.60	0.5	0.50	0.3	0.30	0.5	0.50	0.3	0.30	0.5	0.50	0.4	0.40	--	--	--	--	--	--	--	--	--	--	0.48	11
8	2.3	1.00	1.2	0.54	1.5	0.68	0.8	0.36	1.4	0.68	1.1	0.50	1.1	0.50	0.5	0.22	1.1	0.50	--	--	--	--	--	--	--	--	0.55	11
9	1.4	0.66	1.0	0.47	1.0	0.47	0.7	0.33	0.8	0.38	0.9	0.42	0.9	0.42	1.2	0.57	0.8	0.38	0.9	0.42	1.9	0.90	--	--	--	--	0.49	12
10	1.4	0.77	1.0	0.55	1.0	0.55	0.7	0.38	0.9	0.50	0.9	0.50	0.9	0.50	1.4	0.70	0.7	0.38	0.8	0.42	--	--	--	--	--	--	0.53	11
11	1.3	0.72	0.8	0.44	1.0	0.55	0.3	0.16	1.0	0.55	0.7	0.38	0.7	0.38	1.0	0.55	0.7	0.38	0.8	0.44	--	--	--	--	--	--	0.45	11
12	1.4	1.00	0.8	0.57	1.1	0.78	0.3	0.22	0.7	0.55	0.7	0.55	0.7	0.55	1.0	0.71	1.7	0.12	0.8	0.57	1.1	0.78	0.9	0.13	1.3	0.64	0.55	14
13	0.4	0.21	1.9	1.00	1.3	0.72	1.3	0.72	1.6	0.84	1.3	0.72	1.2	0.62	1.3	0.68	1.2	0.63	1.4	0.73	1.4	0.73	--	--	--	--	0.68	12
14	0.8	0.47	1.5	0.88	1.2	0.70	1.2	0.70	1.1	0.64	1.5	0.88	1.1	0.64	1.3	0.76	1.2	0.70	1.5	0.88	1.5	0.88	--	--	--	--	0.73	12
15	0.7	0.36	1.2	0.62	0.9	0.47	0.9	0.47	1.0	0.52	1.4	0.73	0.6	0.31	1.3	0.68	--	--	--	--	--	--	--	--	--	--	0.52	9
16	0.6	0.31	1.1	0.57	1.2	0.62	1.2	0.62	1.5	0.78	1.2	0.62	0.3	0.15	1.3	0.68	1.3	0.68	1.3	0.68	1.4	0.73	--	--	--	--	0.58	12

1 - 4 Check.

5 - 8 Hydrazine sulphate and alum, 1 gm. in 94.63 cc. water

9 -12 Sucrose, 1 gm. in 181.9 cc. water

13 -16 Floralife, 1 gm. in 30.5 cc. water

flower and, second, to determine if transpiration was affected by the various chemicals.

From these experiments the following conclusions were reached:

(1) The rose is the most suitable flower to work with as it was definitely affected by the chemicals in most cases. In addition to the results reported several tests were run with roses in Floralife solution which were held under room conditions. It was found the chemical solution was beneficial in all cases. It is less difficult to determine when a rose is ready to be discarded than, for instance, a daisy, or one of the species whose bloom consists of many small individual flowers, like the lupin or geranium. As roses are relatively short-lived flowers the beneficial effects of a chemical in prolonging their lives are more marked than on flowers which normally live for a considerable period of time. The fact that roses are the most important commercial flower and therefore available at all times was also considered in this decision.

(2) The chemical mixture Floralife was chosen for further study because it gave fairly definite results with roses and several other flowers. It also appeared to modify transpiration rate and it was thought likely that it would also affect other physiological processes.

(3) It appeared that low transpiration rate was correlated with improved keeping qualities. The increasingly concentrated solution may have somewhat checked absorption of water by the flower and thus tended to produce low transpiration rates. However, the evidence was not conclusive and the study of this

factor was carried on in Part II.

It was thought at the end of this part of the work that more definite conclusions could be drawn if future experiments were limited to one species of flower and studies carried out under controlled conditions. Controlled conditions are necessary as the great amount of individual variation among the flowers in the uncontrolled experiments made it very difficult to draw any conclusions regarding a particular chemical treatment.

EXPERIMENTS - PART II

In these experiments both transpiration and respiration were measured and correlated with keeping quality. The rose variety Pink Briarcliff was used and treated with the chemical Floralife.

Methods

Measurement of Transpiration

The setup was essentially the same as that described in connection with the experiments in Part I and is shown in Figure 6. Attention is drawn to the fact that each figure represents the transpiration of four flowers, not one as in the first experiments. A glass tube was inserted in the cork and each day after the setup had been weighed water was added to bring the weight of the setup to the initial weight; this procedure was designed to offset any deleterious effect on the flowers that an increasingly concentrated solution might have. The setup was weighed once in twenty-four hours and transpiration rate recorded as water loss in grams per gram initial wet weight of tissue per twenty-four hours. In these experiments a more accurate balance was used than in the first part of the work and the figures are accurate to the first decimal place.

Measurement of Respiration

The respiration intensity of living tissue can be expressed by carbon dioxide evolution, oxygen uptake or amount of substrate decomposed. It is the carbon dioxide evolution method



Figure 6

The setup of the roses.

which was used in this work. An apparatus is necessary for this purpose and it was decided to use the gas train system in which carbon dioxide free air is passed over the respiring material and then bubbled through barium hydroxide solution; the carbon dioxide given off by the material is precipitated as barium carbonate and the residual barium hydroxide titrated with standard acid to determine the amount of carbon dioxide given off in a period of time. One of the three trains of the apparatus is shown in Figure 7.

General Description

The air enters at the extreme left of the figure, passes over the soda lime in the soda lime tower A, where the carbon dioxide is removed. The bottle of barium hydroxide B serves as a check on the complete absorption of the carbon dioxide by the soda lime. The carbon dioxide free air then passes into the flower chamber C where it becomes charged with carbon dioxide from the respiring plant material. This chamber consists of a metal cylinder which sits in a pan divided into two sections; the outer section is filled with a pure paraffin oil to make an airtight seal and in the inner section are placed the flowers. The carbon dioxide charged air leaves the plant chamber and enters the absorption tower D. This absorption tower is described by Truog (23). It consists of a heavy walled suction flask in which is set a piece of glass tubing containing a mixture of glass beads and pieces of capillary tubing. The beads and tubing help to increase the surface of barium hydroxide exposed to the incoming air. In the top of the tower

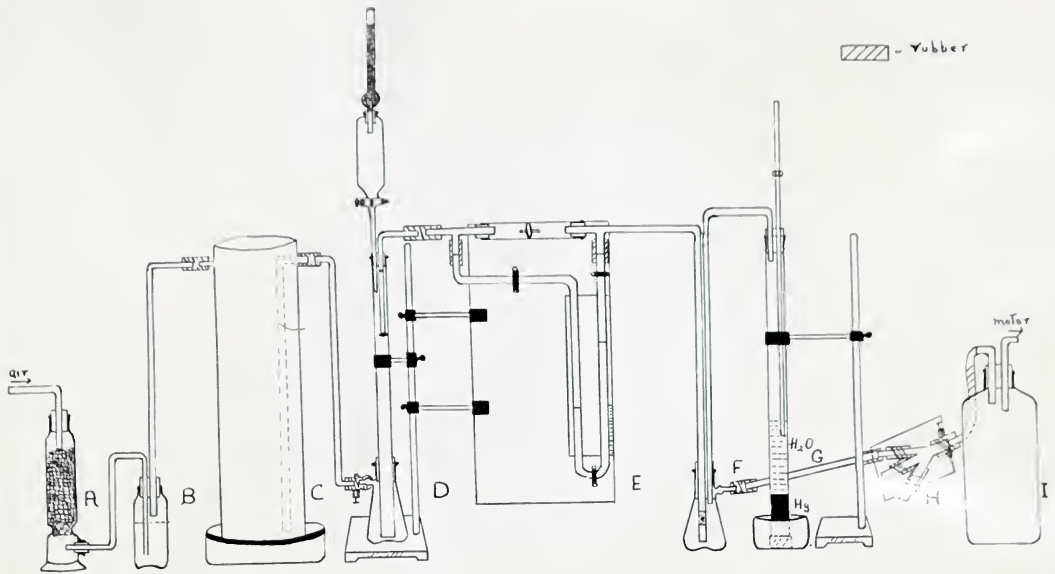


Figure 7

One of the gas trains in the respiration apparatus.

Note: For description see page 36.

is placed a dropping funnel fitted with a soda lime tube which holds the barium hydroxide at the beginning of the experiment. The glass tubing connecting the tower with the flowmeter is fitted with a small piece of solid glass flattened at one end to break the air bubbles rising up in the tower. In the absorption tower the carbon dioxide in the air from the flower chamber is precipitated as barium carbonate, the residual barium hydroxide being titrated with acid. The flowmeter E is essentially a resistor (a small piece of fine capillary tubing) and gauge on which to read the difference in air pressure across the resistor. The meter consists of two arms connected to the air line, one ahead of and the other following the resistor. The reading gives the difference in air pressure before and after the air has passed through the resistor. The liquid used in the gauge was a mixture of oil and a red dye Sudan III. Following the flowmeter is the safety flask F, the important part of which is the Bunsen valve at the end of the delivery tube. The valve consists of a short piece of rubber tubing slit on the side and plugged with a piece of solid glass rod. The valve opens easily with pressure from the inside but closes on back pressure. G represents the pressure regulator which adjusts the unequal resistances of the three gas trains attached to the same suction pump. When the by-pass tube is up the air goes into the regulator and out through the tube as the path of least resistance; when the tube is pushed into the mercury the resistance to air flow is stepped up. H shows the outlets to each of the trains, each one controlled by a stopcock and I is the safety bottle

where pressure can build up without doing any harm. All three trains were attached to a suction pump which is not shown.

Each flowmeter was calibrated and the method is shown in Figure 8. The method used is in principle that described by Smith (19). The water running into the large Erlenmeyer flask B, from the reservoir A, displaces air which is forced through the flowmeter C, the air pressure thus generated being recorded in the changing levels of the liquid on the gauge. This pressure forces water out of the bottle D and into the graduated cylinder E at a rate depending on how rapidly the water enters the flask B. By a small stopcock on B one can adjust the pressure to a given reading on the scale. The rate at which the water is delivered to the graduate cylinder is taken as the rate of flow through that meter at the reading shown on the gauge. The amount of water delivered to the cylinder in two minutes was recorded and the amount that would be delivered in one hour calculated. A number of measurements were taken at different readings and the readings were plotted against the rate of flow on a graph to give a curve from which could be read the reading on the flowmeter for any desired rate of flow.

Procedure in Measurement of Respiration

The flowers were placed in the plant chambers, the dropping funnels filled with barium hydroxide (.049 N) and the system started running. The rate of flow used was 17 litres per hour. Aspiration was carried on for two hours before the barium hydroxide was run into the towers to allow the plant material to come to equilibrium and to free the train of any air

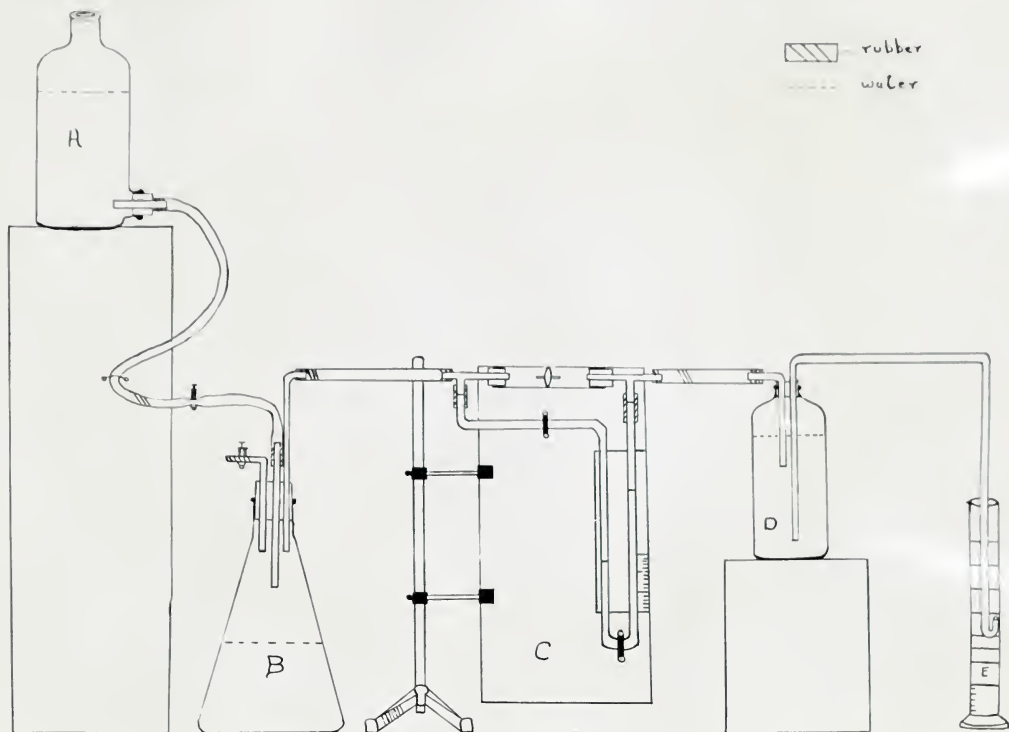


Figure 8

The apparatus for the calibration of a flowmeter.

which might have entered before the system was connected up. Then the barium hydroxide was run into the towers followed by carbon dioxide free water and the apparatus started running. At the end of two hours the air flow was stopped, the towers disconnected from the plant chambers and the parts washed down with carbon dioxide free water. The solution in the flask which consisted of barium carbonate, barium hydroxide and water was titrated immediately with .05 N hydrochloric acid in the presence of the indicator phenolphthalein. The titration thus obtained was used to calculate the amount of carbon dioxide liberated by the flowers. The following equation taken from Loomis and Shull (7) was used:

$$\text{mgms. carbon dioxide} = V \times N \times 22.0$$

where V is the difference between the blank and the experimental titration, N is the normality of the acid and 22 is the normal weight of carbon dioxide. The procedure is essentially that described by Martin and Green (9) although they did not use the same apparatus.

Before the apparatus was used in experiments with flowers many trial runs were made to check for leaks and a great deal of time was expended before the system was considered as accurate as possible. Two types of checks were made: (1) The soda lime towers were disconnected and air was aspirated through the system for one hour. The results varied from time to time as the carbon dioxide content of the air is not constant but as all three trains always registered the same amount in a given run it was concluded that the apparatus was sufficiently

standardized. (2) The second method was to aspirate with carbon dioxide free air for the same period the experiments were run, that is two hours, and titrate the barium hydroxide to determine if any carbon dioxide had been passing through the system. Although absolute air-tightness could not be achieved in the time at the writer's disposal the errors were small and practically the same for all three trials. These errors were not considered serious as it was relative not absolute differences that were sought in these experiments. The respiration results were expressed as milligrams carbon dioxide per gram initial wet weight of flower tissue per two hours.

With regard to the general procedure of the experiments with roses, the flowers were set up in the containers immediately they were received; the flowers were shipped from an eastern greenhouse to a local florist from whom they were obtained the day they arrived. The flowers were remarkably uniform week after week and all in the loose bud stage.

Results

Preliminary Experiments

Four preliminary experiments were run with the roses to gain a knowledge of how they reacted.

Experiment I

Material: Roses, variety Pink Briarcliff, in loose bud stage.

Chemicals: Floralife. (It might be noted that the materials and chemicals are the same for all subsequent experiments.)

Conditions: The roses were set up in containers, four roses to a container. One of the containers held double distilled water, A in the results, the other two held chemical solution, B and C in the results. Eight flowers were placed in solution to offset the effects of individual variation on the results. (The above conditions apply to all rose experiments.) In this experiment the flowers were set up without any preliminary treatment and the concentration of chemical used was 1 gram in 113.1 cc. of double distilled water (10 grams per quart approximately).

Results: See Table 7.

Table 7. Results, Experiment 1

Days	Respiration			Transpiration			Temperature
	A	B	C	A	B	C	
1	24.81* 0.54	23.33 0.61	24.76 0.62	10.80** 0.24	10.65 0.28	9.31 0.23	23.4°C.
2	26.44 0.58	26.51 0.69	25.80 0.65	17.11 0.38	12.05 0.32	9.90 0.25	23.7°C.
3	18.31 0.40	25.97 0.68	26.40 0.66	17.00 0.38	13.40 0.35	15.50 0.39	23.8°C.

* In each day the upper figure is the carbon dioxide evolution in milligrams, the lower figure the respiration rate in milligrams.

**In each day the upper figure is the water loss in grams, the lower figure the transpiration rate in grams.

A - Check.

B and C - In solution (replicates).

Experiment 2

Conditions: The same as in Experiment 1.

Results: See Table 8.

Table 8. Results, Experiment 2

Days	Respiration			Transpiration			Temperature
	A	B	C	A	B	C	
1	21.96* 0.53	21.25 0.56	22.24 0.57	8.50** 0.20	9.40 0.25	9.29 0.24	23.4°C.
2	23.58 0.57	21.59 0.57	24.04 0.61	9.30 0.22	11.75 0.31	12.10 0.34	23.7°C.
3	27.82 0.67	26.85 0.71	25.41 0.65	11.20 0.27	18.00 0.48	11.85 0.30	23.8°C.

*) - See footnotes, Table 7 (page 47).
 **)

Remarks: The flowers lasted four days, but after the first two days there was considerable discoloration and wilting of the petals in both checks and treated flowers. As the petals of this variety of rose do not fall until long after they would have been discarded the characters of petal color, petal turgidity and flower odor will have to be used in deciding when to discard the flowers.

Experiment 3

Conditions: One dozen roses measured for respiration and transpiration twice per day. One dozen held in the room, six in water, six in Floralife, and no measurements taken on them. The concentration of Floralife solution was raised to 1 gram in 30.3 cc. of water

(37 grams per quart approximately).

Results: See Table 9.

Table 9. Results, Experiment 3

Days	Respiration			Transpiration			Temperature
	A	B	C	A	B	C	
1	21.09* 0.76	21.01 0.85	20.66 0.78	--	--	--	23.9°C.
2	20.55* 0.74 17.69* 0.64	20.21 0.82 20.25 0.82	21.23 0.81 21.65 0.82	6.61** 0.24 0.30** 0.01	5.80 0.24 0.40 0.02	6.44 0.24 0.11 0.004	22.0°C.
3	22.27 0.80 22.87 0.83	22.18 0.90 20.44 0.83	22.97 0.87 23.08 0.88	7.81 0.28 0.30 0.01	5.65 0.23 0.40 0.02	7.19 0.27 0.00 0.00	22.0°C.
4	--	--	--	--	--	--	
5	21.72 0.78 15.67 0.57	19.21 0.78 16.94 0.69	25.15 0.95 22.20 0.84	17.90 0.65 0.70 0.03	11.80 0.48 0.30 0.01	17.85 0.68 1.40 0.05	22.6°C.
6	-- --	17.60 0.72	24.20 0.92	-- --	5.08 0.21	10.48 0.40	22.6°C.

*) - See footnotes, Table 7 (page 47).
 **)

Remarks: It was found that flowers held in the room did not last longer than those being measured for respiration and transpiration, therefore it was concluded that the flowers were not being injured by the measurements, in particular, the low humidity of the air in the respiration apparatus. Two readings a day are not necessary either in respiration or transpiration records.

ORIGINAL ARTICLES

Title	Author			Editor			Page
	First	Second	Third	First	Second	Third	
1. The Effect of the Diet on the Blood Sugar	—	—	—	25.0	10.0	20.0	1
2. The Effect of the Diet on the Blood Sugar	10.0	10.0	10.0	10.0	10.0	10.0	2
3. The Effect of the Diet on the Blood Sugar	10.0	10.0	10.0	10.0	10.0	10.0	3
4. The Effect of the Diet on the Blood Sugar	10.0	10.0	10.0	10.0	10.0	10.0	4
5. The Effect of the Diet on the Blood Sugar	10.0	10.0	10.0	10.0	10.0	10.0	5
6. The Effect of the Diet on the Blood Sugar	10.0	10.0	10.0	10.0	10.0	10.0	6
7. The Effect of the Diet on the Blood Sugar	10.0	10.0	10.0	10.0	10.0	10.0	7
8. The Effect of the Diet on the Blood Sugar	10.0	10.0	10.0	10.0	10.0	10.0	8
9. The Effect of the Diet on the Blood Sugar	10.0	10.0	10.0	10.0	10.0	10.0	9
10. The Effect of the Diet on the Blood Sugar	10.0	10.0	10.0	10.0	10.0	10.0	10

THE JOURNAL OF THE AMERICAN MEDICAL ASSOCIATION

Published by the American Medical Association, 535 North Dearborn Street, Chicago, Ill. 60610. Second-class postage paid at Chicago, Ill., and at additional mailing offices. Postmaster: Send address changes in this journal to THE JOURNAL OF THE AMERICAN MEDICAL ASSOCIATION, 535 North Dearborn Street, Chicago, Ill. 60610. This journal is published weekly, except for two issues combined annually in November and December. Subscription price, \$10.00 per annum in advance. Single copies, 25 cents. Entered as second-class matter, May 2, 1917. Postoffice at Chicago, Ill., has special authority for sale of copies at special rate of 10 cents per copy. Acceptance for mailing at special rate of 10 cents per copy provided for in Section 1103, Act of October 3, 1917. Authorized agent for sale, The American Medical Association, 535 North Dearborn Street, Chicago, Ill. 60610.

The flowers lasted longer than in the first two experiments, checks five days and treated flowers six days, and petal color and turgidity were improved. It is thought that increased concentration of the solution is justified. Trouble was experienced with unopened buds which merely wilted and died; of course this would affect the results as each figure represents four flowers. The respiration results are shown graphically in Figure 9, page 52.

Experiment 4

Conditions: Flowers "hardened" 48 hours at 6°C. before they were set up in the containers, instead of setting up immediately they were received as had been the practice. Hardening is holding the flowers in a cool dark place in a deep container of cool water. One dozen roses were measured for respiration and transpiration and one-half dozen were again held in the room. Increased concentration of solution retained.

Results: See Table 10.

Remarks: It was found that hardening is beneficial as it does away with the trouble of unopened buds and in general the flowers stood up much better than when they had not been hardened. The roses did not last any longer when they were not tested for respiration and transpiration. The checks lasted five days, the treated flowers seven days.

Table 10. Results, Experiment 4

Days	Respiration			Transpiration			Temperature
	A	B	C	A	B	C	
1	29.49* 0.65	27.96 0.64	29.08 0.60	--	--	--	23.0°C.
2	22.78 0.50	27.25 0.63	24.99 0.52	11.00** 0.24	10.80 0.25	12.30 0.27	22.9°C.
3	20.51 0.45	29.32 0.67	28.34 0.60	9.40 0.21	8.71 0.20	11.60 0.24	22.0°C.
4	18.90 0.41	31.25 0.72	32.26 0.67	11.50 0.25	11.15 0.26	12.90 0.27	25.0°C.
5	--	--	--	--	--	--	
6	--	--	--	--	21.20 0.49	35.50 0.73	24.0°C.

*) - See footnotes, Table 7 (page 47).
 **)

Main Large Experiment

Following the preliminary experiments a large experiment was set up consisting of ten experiments, each employing one dozen roses and all carried out under the same conditions. It is from this experiment that most of the final conclusions are drawn.

Conditions: Floralife used in the concentration of 1 gram in 30.5 cc. distilled water. Flowers hardened twenty-four hours at 3°C. Four flowers in each experiment were in distilled water, eight in chemical solution. Respiration and transpiration were measured once a day. Extreme care was taken in all procedures to have exactly

the same conditions for each of the ten experiments.
Flowers protected from drafts and sunlight.

Table 11. Results, Experiment 1

Days	Respiration			Transpiration			Temperature
	A	B	C	A	B	C	
1	25.90* 0.93	26.83 0.81	25.95 0.85	--	--	--	21.5°C.
2	25.96 0.93	27.48 0.83	29.03 0.95	5.10** 0.18	6.40 0.19	7.30 0.24	21.5°C.
3	26.99 0.97	28.80 0.87	27.94 0.92	6.00 0.20	5.80 0.17	6.10 0.20	20.0°C.
4	25.18 0.90	28.98 0.87	27.67 0.91	6.70 0.24	8.60 0.26	7.40 0.24	20.5°C.
5	--	--	--	--	--	--	
6	--	--	--	13.70 0.49	16.60 0.50	15.71 0.52	21.0°C.

*) - See footnotes, Table 7 (page 47).
**)

Remarks: The flowers in solution lasted six days; the flowers in distilled water lasted five days. Also, treated flowers had better appearance throughout the experiment in regard to color and turgidity of petals. Roses in water faded rapidly.

Table 12. Results, Experiment 2

Days	Respiration			Transpiration			Temperature
	A	B	C	A	B	C	
1	26.05* 0.94	26.52 0.82	27.02 0.80	--	--	--	21.5°C.
2	25.57 0.92	27.77 0.86	26.60 0.78	6.50** 0.21	7.90 0.25	6.11 0.18	21.5°C.
3	28.05 0.90	27.99 0.87	29.61 0.87	8.20 0.26	16.50 0.51	4.92 0.15	20.0°C.
4	24.91 0.80	28.05 0.87	30.07 0.89	10.60 0.34	10.00 0.31	8.00 0.24	20.5°C.
5	--	--	--	--	--	--	
6	--	--	--	13.70 0.44	16.60 0.52	15.71 0.47	21.9°C.

Remarks: Flowers in solution lasted six days, checks five days.

Table 13. Results, Experiment 3

Days	Respiration			Transpiration			Temperature
	A	B	C	A	B	C	
1	26.96* 0.68	27.23 0.68	27.59 0.76	--	--	--	22.1°C.
2	26.47 0.66	26.45 0.66	28.39 0.78	7.20** 0.18	9.60 0.24	5.60 0.15	21.9°C.
3	24.49 0.62	28.26 0.70	29.12 0.80	9.20 0.23	8.80 0.22	7.30 0.20	22.0°C.
4	23.83 0.60	29.37 0.73	30.66 0.84	13.40 0.34	13.30 0.33	9.90 0.27	20.5°C.
5	23.86 0.60	31.09 0.78	30.11 0.83	5.50 0.14	6.75 0.17	6.90 0.19	19.8°C.
6	--	--	--	--	--	--	
7	--	--	--	--	29.20 0.73	20.20 0.55	20.0°C.

Remarks: Treated flowers lasted six days, checks four days.

*) - See footnotes, Table 7 (page 47).
 **)

Table 14. Results, Experiment 4

Days	Respiration			Transpiration			Temperature
	A	B	C	A	B	C	
1	27.02* 0.69	26.94 0.70	27.12 0.92	--	--	--	22.1°C.
2	26.96 0.69	27.23 0.71	26.52 0.90	8.10** 0.22	7.02 0.18	7.60 0.24	21.9°C.
3	27.20 0.70	29.77 0.77	27.25 0.93	10.10 0.26	7.90 0.20	6.30 0.19	22.0°C.
4	24.45 0.63	30.58 0.79	28.34 0.96	16.00 0.41	13.60 0.35	12.00 0.36	20.5°C.
5	24.90 0.64	31.62 0.82	32.55 0.99	6.30 0.16	7.48 0.19	6.30 0.19	19.8°C.
6	--	--	--	--	--	--	
7	--	--	--	--	16.30 0.42	23.60 0.72	20.0°C.

Remarks: Flowers in solution in excellent shape on day seven; that is, treated flowers lasted seven days, checks four days.

Table 15. Results, Experiment 5

Days	Respiration			Transpiration			Temperature
	A	B	C	A	B	C	
1	31.07* 0.66	30.29 0.73	31.08 0.71	--	--	--	25.0°C.
2	28.60 0.61	29.45 0.71	28.83 0.66	13.20** 0.28	9.11 0.22	8.20 0.19	21.1°C.
3	30.09 0.64	27.48 0.67	30.07 0.69	9.50 0.20	8.80 0.21	9.10 0.21	20.5°C.
4	29.76 0.63	30.17 0.73	30.07 0.69	15.40 0.33	9.80 0.24	10.30 0.24	22.0°C.
5	29.55 0.63	30.07 0.73	29.40 0.67	9.10 0.19	16.00 0.39	16.25 0.37	22.6°C.

Remarks: Flowers lasted in water four days, in solution six.

*)
**) - See footnotes, Table 7 (page 47).

Table 16. Results, Experiment 6

Days	Respiration			Transpiration			Temperature
	A	B	C	A	B	C	
1	29.65* 0.64	28.53 0.62	28.50 0.65	--	--	--	25.0°C.
2	25.93 0.56	25.37 0.55	25.73 0.58	8.50** 0.18	12.20 0.27	9.80 0.22	21.1°C.
3	22.54 0.48	29.64 0.65	29.14 0.66	8.60 0.18	8.60 0.19	7.21 0.16	20.5°C.
4	26.97 0.58	28.05 0.61	28.52 0.65	10.20 0.22	18.11 0.40	11.00 0.25	22.0°C.
5	26.84 0.58	28.00 0.61	27.69 0.63	10.00 0.22	15.50 0.34	11.31 0.26	22.6°C.

Remarks: Flowers lasted in solution six days, in water four.

Table 17. Results, Experiment 7

Days	Respiration			Transpiration			Temperature
	A	B	C	A	B	C	
1	26.83* 0.65	25.91 0.57	25.99 0.67	--	--	--	19.0°C.
2	28.01 0.68	27.86 0.61	30.59 0.76	7.10** 0.17	10.11 0.22	11.00 0.28	20.8°C.
3	28.83 0.69	32.34 0.71	32.55 0.81	10.30 0.25	10.50 0.23	10.10 0.25	21.0°C.
4	22.11 0.53	32.55 0.72	28.83 0.72	12.00 0.29	14.61 0.31	11.50 0.29	22.0°C.
5	--	--	--	--	--	--	
6	--	--	--	22.90 0.55	34.30 0.76	29.51 0.71	22.6°C.

Remarks: Flowers opened rapidly and were full out the second day. Treated flowers lasted seven days, checks five days.

*) - See footnotes, Table 7 (page 47).
 **)

Table 18. Results, Experiment 8

Days	Respiration			Transpiration			Temperature
	A	B	C	A	B	C	
1	26.05* 0.67	25.93 0.70	25.50 0.64	--	--	--	19.0°C.
2	26.85 0.69	30.70 0.25	29.90 0.72	9.61** 0.25	5.40 0.15	6.50 0.18	21.9°C.
3	26.97 0.70	31.57 0.86	28.21 0.71	11.40 0.29	8.20 0.17	7.02 0.18	22.5°C.
4	26.40 0.68	32.25 0.87	27.28 0.68	12.40 0.32	8.11 0.22	11.20 0.28	23.6°C.
5	--	--	--	--	--	--	
6	--	--	--	20.40 0.53	22.40 0.61	20.80 0.52	22.0°C.

Remarks: Flowers lasted in solution six days, in water five.

Table 19. Results, Experiment 9

Days	Respiration			Transpiration			Temperature
	A	B	C	A	B	C	
1	25.73* 0.61	25.98 0.64	26.04 0.61	--	--	--	21.9°C.
2	27.26 0.65	25.10 0.62	26.64 0.63	12.10** 0.29	8.15 0.20	8.70 0.21	21.9°C.
3	32.81 0.78	33.27 0.80	33.69 0.79	12.60 0.30	8.71 0.22	9.72 0.23	21.2°C.
4	24.90 0.59	30.14 0.75	29.76 0.70	12.50 0.30	10.00 0.25	10.90 0.26	20.5°C.
5	--	29.65 0.74	30.17 0.71	12.00 0.29	11.60 0.29	13.00 0.31	21.0°C.
6	--	--	--	--	--	--	
7	--	--	--	--	25.10 0.62	27.80 0.66	21.0°C.

Remarks: Treated flowers lasted 6 days, checks 3 days.

*) - See footnotes, Table 7 (page 47).
 **)

Table 1. Results of the first series of experiments

No. of the experiment	Initial conditions			Final conditions			Remarks
	Time, min	Temperature, °C	Pressure, mm Hg	Time, min	Temperature, °C	Pressure, mm Hg	
1	0	20.0	760.0	10	20.0	760.0	I
2	0	20.0	760.0	10	20.0	760.0	II
3	0	20.0	760.0	10	20.0	760.0	III
4	0	20.0	760.0	10	20.0	760.0	IV
5	0	20.0	760.0	10	20.0	760.0	V
6	0	20.0	760.0	10	20.0	760.0	VI
7	0	20.0	760.0	10	20.0	760.0	VII
8	0	20.0	760.0	10	20.0	760.0	VIII
9	0	20.0	760.0	10	20.0	760.0	IX
10	0	20.0	760.0	10	20.0	760.0	X

Notes: 1. The results of the first series of experiments are given in Table 1.

Table 2. Results of the second series of experiments

No. of the experiment	Initial conditions			Final conditions			Remarks
	Time, min	Temperature, °C	Pressure, mm Hg	Time, min	Temperature, °C	Pressure, mm Hg	
1	0	20.0	760.0	10	20.0	760.0	I
2	0	20.0	760.0	10	20.0	760.0	II
3	0	20.0	760.0	10	20.0	760.0	III
4	0	20.0	760.0	10	20.0	760.0	IV
5	0	20.0	760.0	10	20.0	760.0	V
6	0	20.0	760.0	10	20.0	760.0	VI
7	0	20.0	760.0	10	20.0	760.0	VII
8	0	20.0	760.0	10	20.0	760.0	VIII
9	0	20.0	760.0	10	20.0	760.0	IX
10	0	20.0	760.0	10	20.0	760.0	X

Notes: 1. The results of the second series of experiments are given in Table 2.

$$f = \frac{1}{2} \left(\frac{v_1}{v_2} + \frac{v_2}{v_1} \right)$$

Table 20. Results, Experiment 10

Days	Respiration			Transpiration			Temper- ature
	A	B	C	A	B	C	
1	26.25* 0.60	26.85 0.52	25.97 0.57	--	--	--	21.2°C.
2	25.23 0.58	24.28 0.56	26.78 0.57	10.40** 0.24	10.70 0.25	13.11 0.28	21.9°C.
3	27.29 0.62	30.48 0.71	31.21 0.66	10.90 0.25	9.40 0.22	10.90 0.23	21.2°C.
4	23.25 0.53	30.88 0.71	31.47 0.67	9.30 0.21	10.40 0.24	11.62 0.25	20.5°C.
5	--	30.07 0.70	28.80 0.61	9.92 0.23	12.30 0.28	12.30 0.26	21.0°C.
6	--	--	--	--	--	--	
7	--	--	--	--	28.40 0.66	28.10 0.59	21.0°C.

Remarks: Flowers in solution lasted six days, those in water three days.

*)
**) - See footnotes, Table 7 (page 47).

The results of this large experiment are shown in Figure 4, page 27, and Figure 9, page 58. From the results of this experiment it appears that transpiration rate is not affected by the Floralife solution. Attention is drawn to the fact that the averages may not give a true picture as there was so much variation in the transpiration figures. The flowers in Floralife solution showed respiration rates which were higher than those of the flowers in water. Again, the averages may not be justified although there was not so much variation in the respiration figures as in the transpiration figures.

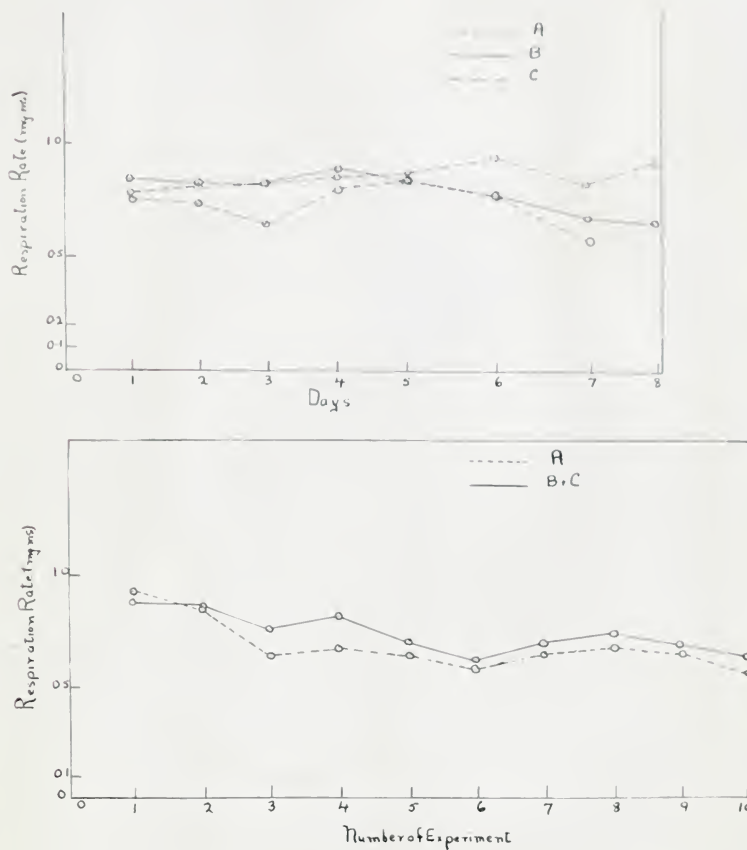


Figure 9

(1) The respiration results from Experiment 3 (preliminary experiments, roses). (Upper graph)

(2) The respiration results from the main experiment with roses. (Lower graph)

Note: Each point on broken line represents the average respiration rate of the flowers in water, each point on the continuous line the average rate of the flowers in chemical solution.

DISCUSSION

Generally speaking, the keeping qualities of a cut flower depend on a number of interdependent factors such as: specific nature, methods of cultivation, maturity, time of cutting and subsequent treatment. The failure to take all these factors into consideration leads to inconclusive experimental results. These experiments have been concerned with the factor of subsequent treatment and the other factors have been controlled as carefully as possible.

From the experiments in Part I it appears that in general the chemical mixture Floralife (alum, hydrazine sulphate, sucrose plus an alcohol soluble substance, undetermined) has a beneficial effect on the flowers tested and also that it tends to decrease transpiration rate at the same time. These data would lead one to believe that reduced transpiration rate is correlated with improved keeping quality of the flower. (The term "correlated" is meant only in the general sense and does not imply statistical analysis of results.)

In the work in Part II a more intensive and better controlled set of experiments was undertaken to discover if the physiological processes of transpiration and respiration were related to the keeping qualities of cut flowers, in this case roses, variety Pink Briarcliff. In the following discussion the two processes will be dealt with separately.

1. Transpiration

Transpiration is the loss of water from the plant, or

in this case the flower, in the form of vapour. Wilting occurs when transpiration rate exceeds the absorption of water through the cut end of the flower stem. It is well to keep in mind the fact that the transpiration of a cut shoot does not necessarily bear any relation to the transpiration of the shoot when attached to the plant. There has not been any work, comparable to that of Kidd, West and Briggs (4), done on the effect of maturity on the transpiration of the whole plant or of its organs (in the available literature). However, most workers assume that fresh flowers have a high transpiration rate and that this is an indication that the flower is rapidly absorbing water. Ries (18) states, "Most flowers absorb a maximum amount of water in the fresh condition; this quality gradually falls off and drops fairly rapidly as the flowers die." It would appear then, that a treatment which would keep the flowers fresh longer would cause them to transpire more water. Thus a search should be made for a chemical or chemicals which increase transpiration rate and these would be expected to improve keeping quality. This is the theory of Laurie (6) who states that a beneficial chemical must increase transpiration rate. Hitchcock and Zimmerman (3) found that although many of the chemicals they tested decreased transpiration rate the flowers which lasted best lost the greatest amounts of water daily.

It is recognized that both low temperature and high percentage humidity improve the keeping qualities of flowers and since transpiration rate is reduced under both these conditions it would be reasonable to suppose that a favorable chemical would not increase but decrease transpiration rate. The results in

Part I would point to decreased transpiration rate as being related to improved keeping quality in most cases. On the other hand, Neff (13) found that water loss was the same for fresh carnations, dry pack carnations and those stored with stems in water. Since these treatments gave very different results in regard to keeping time Neff suggests that this might preclude the idea that increased life of flowers at room temperature depended on higher transpiration rate or indeed was even related to transpiration rate.

The data in Part I might indicate that the trend of transpiration rate in a flower is to show a low rate at the beginning of the experiment rising to a peak and falling off toward the end of the life of the flower as Ries (12) suggests. However, under controlled conditions in Part II this trend was not noticeable with roses, either in water which may be considered under normal conditions as compared with those in solution, or in chemical solution.

Is transpiration related to keeping quality? If transpiration rate were related to keeping quality one would expect that the rates would vary as length of life varied. That is, roses in water would show different rates from roses in chemical solution as the latter lasted longer. However, on the basis of the data obtained in these experiments it is concluded that transpiration rate is not related to keeping quality in Pink Briarcliff roses.

2. Respiration

Although the literature would indicate that water relations of flowers ^{is} ~~are~~ the most important factor in connection

With keeping quality it was thought that respiration should be affected if keeping quality was improved. Respiration is a process which involves all the chemical reactions by which complex organic substances are broken down in the plant with the release of energy and its outward manifestations are the absorption of oxygen and the release of carbon dioxide. As respiration is a characteristic of every living tissue it is reasonable to suppose that any treatment which affects the developmental cycle of an organ would also have an effect on respiration. Kidd, West and Briggs (4) have shown that the respiration rate, not only of the entire plant (in this case Helianthus annuus) but also of the individual organs decreases with increasing age.

Except for a suggestion by Laurie (6) that a desirable chemical should be expected to reduce respiration rate this factor has not been considered in connection with this problem. In these experiments the roses in water showed a low respiration rate in the bud stage, an increasing rate up to the open flower which was held for a period, and then, a decreasing rate as the flowers grew old. This behavior is what one would expect. However, the roses in Floralife solution, while starting off with a low respiration rate at the beginning of the experiment and showing a rising rate as the flower opens, do not, in most cases, show the decrease in rate at the end of the experiment found with the flowers in water. As the flowers in solution lasted longer than those in water the final measurements were taken while the flowers were still in good condition, while the final rates for the check flowers were recorded when the flowers were ready

to be discarded. The fact that the respiration rates stayed high longer for those flowers in chemical solution may indicate that the developmental cycle of the treated flowers was somewhat slowed down. However, daily respiration rates of the treated flowers were not consistently lower than those of the checks. With regard to the high respiration rates it might be that the treated flowers lasted longer because nutrients were available in the form of hydrolyzed sugars as the Floralife contains sucrose. Thus the higher respiration rates may indicate that these flowers have more respiration substrate available than the flowers in water. This might explain why the treated flowers lasted better. It must be remembered that the flower attached to the plant has at all times a steady supply of nutrients while a cut flower must depend on what it has stored in its stem, leaf and petal cells which may not be sufficient as this emergency would naturally not be provided for in nature.

However, on the basis of these experiments it is concluded that it is not advisable at this point to make a definite statement as to whether respiration is related to keeping quality in roses. It would be necessary to obtain more extensive data before a conclusion could be safely drawn.

During the course of these experiments it was observed that several characters of the roses were visibly affected by Floralife. These were petal color, petal turgidity and flower odor. It was noticeable that flowers in solution consistently retained their fresh petal color much longer than those in water. In this regard Neff (15) suggests that the alum ($K_2SO_4 \cdot Al(SO_4)_3 \cdot 24 H_2O$) in the Floralife acts as a mordant and

fixes the anthocyanin pigments in the petals which give the flowers color. It has been shown that anthocyanin pigments mordanted with salts of heavy metals tend to give dyes fast to light. It may be that it also brings about this change in the cells of the flower petals. Concerning petal turgidity Welf also suggests that alum is the active agent affecting the petal cells in some physiological way. The facts are not known but it is known that aluminium ions in combination with anions of higher valence than one tend to increase the permeability of the cytoplasm in certain cases. It was seen that the first indication of loss of freshness in these roses was loss of flower odor which was generally replaced by a stale smell. What mechanism controls this character is not known.

With regard to future work on this problem the writer believes two things are essential: first, a constant temperature room in which to keep the flowers, and second, the facilities to grow the flowers in sufficient quantities. Before the keeping qualities of cut flowers can be improved each species of flower must be studied physiologically under both normal and abnormal conditions.

SUMMARY

1. The object of these experiments was to discover if certain physiological factors or processes are related to the keeping qualities of cut flowers and to determine what this relationship might be.

2. On the basis of preliminary experiments with a number of chemicals and species of flowers it was decided to study the effect of the commercial chemical mixture Floralife on roses. The variety used was Pink Briarcliff.

3. The experiments reported in this thesis show that Floralife is beneficial to this variety of rose and prolongs the life of the flower two days on the average. However, the concentration used was 37 grams per quart of water--about three times the concentration generally recommended.

4. On the basis of these experiments it is concluded that transpiration rate is not related to keeping quality in Pink Briarcliff roses.

5. No definite conclusion is drawn as to whether respiration rate is related to keeping quality. It appears from this work that the respiration rates of the flowers in Floralife were higher than those in water.

6. Observations made during the course of the experiments would lead one to think that the characters of petal color and petal turgidity are important and chemicals should be sought that would aid in maintaining these characters in a desirable condition.

7. The first indication of loss of freshness in these roses was loss of flower odor. The mechanism is not understood.

ACKNOWLEDGMENTS

This work was undertaken as a joint project between the Department of Horticulture and the Department of Botany. The writer wishes to express her thanks to Dr. J. S. Shoemaker of the Department of Horticulture under whose direction this work was undertaken, to Dr. J. H. Whyte and Dr. E. H. Moss of the Department of Botany, the former for invaluable assistance during the first year of the work and the latter for constant encouragement and advice. A grant from the Carnegie Corporation Research Fund made possible the purchase of equipment and materials used in this work.

REFERENCES

1. FOURTEN, L. and DUCOMET, V. Sur la conservation des fleurs coupées. Rev. Horticole 70: 260-262. 1908.
2. GRINSTEAD, H.F. Keeping cut flowers fresh. Garden Mag. 39: 343. 1906.
3. HITCHCOCK, A.E. and ZIMMERMAN, P.W. Effects of chemicals, temperature and humidity on the lasting of cut flowers. Contr. Boyce Thompson Inst. 2: 196-203. 1929.
4. KIDD, F., WEST, C. and BRIGGS, G.E. A quantitative analysis of the growth of Helianthus annuus. Part I. The respiration of the plant and its parts throughout the life cycle. Proc. Roy. Soc. (London) B. '92: 368-384. 1921.
5. KNUDSON, L. Preserving cut flowers. Amer. Flor. 43: 649-650. 1914.
6. LAURIE, A. Studies of the keeping qualities of cut flowers. Proc. Amer. Soc. Hort. Sci. 34: 595-597. 1936.
7. LOOMIS, W.E. and SHULL, C.A. Methods in Plant Physiology. McGraw-Hill Book Co. New York. 1933.
8. LONGLEY, L.E. Some effects of storage of flowers in various gases at low temperature on their keeping qualities. Proc. Amer. Soc. Hort. Sci. 30: 607-609. 1933.
9. MARTIN, W.M. and GREEN, J.R. Determination of carbon dioxide in continuous gas streams. J. Ind. Eng. Chem. 4: 244-245. 1932.
10. MILLER, E.C. Plant Physiology. McGraw-Hill Book Co. 1938.
11. MOLISCH, H. The longevity of plants. The Translator. New York. 1938.
12. NEFF, M.S. and LOOMIS, W.E. Storage of french marigolds. Proc. Amer. Soc. Hort. Sci. 33: 683-685. 1936.
13. _____. Problems in the storage of cut carnations. Plant Physiol. 14: 271-284. 1939.
14. _____. Color and keeping qualities of cut flowers. Bot. Gaz. 101: 501-504. 1939.

15. NEFF, M.S. Effects of storage conditions on cut roses.
Bot. Gaz. 103: 794-805. 1942.
16. PRIDHAM, A.M.S. and THOMPSON, R.G. Factors influencing the
keeping quality of the gladiolus as a cut flower.
Proc. Amer. Soc. Hort. Sci. 27: 289-304. 1930.
17. RATSEK, J.C. Tests metal containers in an attempt to
increase life of cut flowers. Florist's Rev. May 9.
1935.
18. RIES, V.H. How to keep cut flowers fresh. Can. Flor. 35:
312. 1940.
19. SMITH, G.W. Apparatus for calibration of flowmeters.
J. Ind. Eng. Chem. Anal. Ed. 4: 244-245. 1932.
20. STILES, W. and LEACH, W. Respiration in Plants. Methuen
and Co. London. 1932.
21. THORNTON, N.C. The use of carbon dioxide for prolonging
the life of cut flowers with special reference to
roses. Contr. Boyce Thompson Inst. 2: 535-547. 1930.
22. TINCKER, M.A.H. The care of cut flowers. J. Roy. Hort.
Soc. 67: 373-395. 1942.
23. TRUOG, E. Methods for determination of carbon dioxide and
a new form of absorption tower. J. Ind. Eng. Chem.
7: 1045-1049. 1915.
24. WHITEMAN, T.M. and WRIGHT, R.C. Storage of Wedgewood iris
blooms. Proc. Amer. Soc. Hort. Sci. 36: 783-785.
1938.



B29750